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ANISOTROPIC PROPERTIES STUDY OF LAC DU BONNET GRANITE SPECIMENS

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APRIL 1986

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CONTENTS

	Page
INTRODUCTION	1
IDENTIFICATION OF SPECIMENS AND TESTS	1
DESCRIPTION OF TEST MEASUREMENTS	2
DATA TREATMENT	3
DATA SUMMARY	4
FAILURE CHARACTERISTICS	4
ACKNOWLEDGEMENTS	4
REFERENCES	5
APPENDIX A	A-10 to A-41

TABLES

No.		
1.	Summary of sample depth, dimensions, density and orientation	6
2.	Summary of ultrasonic velocity properties	7
3.	Summary of uniaxial compression properties	8

FIGURES

1.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.130 m	42
2.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.185 m	43
3.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.243 m	44
4.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.425 m	45
5.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.570A m	46
6.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.570B m	47
7.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.570C m	48

Contents (cont'd)

		Page
8.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.774 m	49
9.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.892 m	50
10.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 3.979 m	51
11.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 4.048 m	52
12.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-010-MOD1, Depth = 4.102 m	53
13.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.017 m	54
14.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.077 m	55
15.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.137 m	56
16.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.197 m	57
17.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.212 m	58
18.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.337 m	59
19.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.342 m	60
20.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.492 m	61
21.	Axial and circumferential stress/strain curves for anisotropy specimens - Drill hole 206-012-MOD1, Depth = 4.912 m	62

ANISOTROPIC PROPERTIES STUDY OF LAC DU BONNET GRANITE SPECIMENS

by

R. Jackson

Keywords: anisotropy, mechanical rock properties, Young's modulus, uniaxial compressive strength, AECL

INTRODUCTION

As part of the Canadian Nuclear Fuel Waste Management Project (NFWMP), Atomic Energy of Canada Limited (AECL) is characterizing various rock formations to determine their suitability for long term disposal of high level wastes. The program also includes the construction of an underground research laboratory (URL) to provide an opportunity for extensive in situ investigations.

Biaxial testing conducted on core obtained during the construction phase of the URL has indicated that the rock may be anisotropic in terms of modulus of elasticity (1). It was felt that further study in the form of acoustic velocity and uniaxial compression testing could provide additional insight into this behaviour. The program is currently ongoing and will continue as new samples are obtained from the URL site.

This report represents the first of a series of reports which will be published as new data becomes available. No attempt will be made to analyze the data until the program is completed.

IDENTIFICATION OF SPECIMENS AND TESTS

Twenty-one samples were used for this test series; 12 from drill hole 206-010-MOD1 and 9 from drill hole 206-012-MOD1. The location and orientation of the drill holes can be found in Appendix A and are summarized below:

206-010-MOD1:	Collar coordinates:	N 5,570,460.232
		E 295,798.288
		elev. 52.905
	Orientation:	Plunge (dip): -0.6° (up)
		Trend (direction): 025°
206-012-MOD1:	Collar coordinates:	N 5,570,459.711
		E 295,799.653
		elev. 53.186
	Orientation:	Plunge (dip): -02.51° (up)
		Trend (direction): 024.16°

The 45 mm test specimens were prepared by recoring the 200 mm cores obtained from the drill holes along the axes of interest. The specimens were then identified according to their location and orientation as follows:

a) depth of the collar of the 45 mm hole from the collar of the 200 mm hole
b) angle β gives the direction of the 45 mm core in the plane normal to the 200 mm core axis relative to the core orientation mark (clockwise looking down hole)
c) angle α is the angle between the core axis of the 45 mm core and the 200 mm core. The angle is measured clockwise (i.e., dip) from the down hole direction of the 200 mm core.

Table 1 provides a summary of the specimen depth, dimensions, density and orientation. The following properties were determined for the samples listed:

1) compressive wave velocity
2) shear wave velocity
3) uniaxial compressive strength
4) Poisson's ratio, ν
5) dynamic shear modulus, G_d
6) dynamic Young's modulus, E_d
7) Poisson's ratio (determined using velocity measurements), ν_d
8) tangent modulus of elasticity, E_t
9) secant modulus of elasticity, E_s

DESCRIPTION OF TEST MEASUREMENTS

Compression and shear wave velocity measurements were carried out on samples already gauged for elastic deformation measurement. The testing equipment consisted of: transmitting and receiving platens containing piezo-electric transducers, a high voltage pulse generator, a signal amplifier and a Tektronix Type 555 dual beam oscilloscope equipped with delay sweep and a time base resolution of 0.01 micro-seconds/cm. The zero time delay was determined by measuring the time of wave arrival across three steel samples of different lengths. These arrival times could then be extrapolated to correspond to a specimen of zero length.

For an outline of the uniaxial compression procedure, the reader is referred to Technical Data 303410-M01/78 (2). The two Phillips PR 9302 strain bridges and the Mosely Autograph 2FRA X-Y recorder referred to in that document were replaced, in the present study, by two Bruel and Kjaer Type 1526 strain indicators and a Hewlett Packard 7046B X-Y recorder. These equipment

were used to measure and record the axial and transverse strains as a function of axial load. Linear variable differential transducers (LVDT's) were also used to provide redundant measurements of axial deformation.

DATA TREATMENT

The compressional and shear wave velocities were determined by dividing the specimen length by the wave travel time through the specimen. The dynamic properties were, then, calculated using the following equations (3):

Dynamic Shear Modulus

$$G_d = \rho V_s^2 \tag{1}$$

where G_d = dynamic shear modulus
V_s = shear wave velocity
ρ = density

Dynamic Young's Modulus

$$E_d = \frac{\rho V_s^2 (3V_p^2 - 4V_s^2)}{V_p^2 - V_s^2} \tag{2}$$

where E_d = dynamic Young's modulus
V_s = shear wave velocity
V_p = compressional wave velocity
ρ = density

Poisson's Ratio (based on velocity data)

$$\nu_d = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^2)} \tag{3}$$

where ν_d = Poisson's ratio
V_s = shear wave velocity
V_p = compressional wave velocity

The tangent modulus of elasticity (E_t) was calculated for each sample by determining the slope of the tangent to the axial strain curve at 50% of the failure load. The secant modulus of elasticity (E_s) was calculated by

determining the slope of the line joining the origin to the point on the axial strain curve corresponding to 50% of the failure load. The ultimate compressive strength of each sample was calculated by dividing the sample failure load by the sample's cross-sectional area. The ratio of the tangent to the transverse strain curve to the tangent to the axial strain curve at 50% failure load was used to determine the sample Poisson's ratio (ν).

DATA SUMMARY

Table 2 contains the results of the ultrasonic velocity measurements including the calculated values of the dynamic shear modulus, dynamic Young's modulus as well as Poisson's ratio estimated on the basis of velocity data for each sample. Table 3 summarizes the uniaxial compression measurements which include determinations of the loading rate, uniaxial compressive strength, tangent modulus of elasticity, secant modulus of elasticity, Poisson's ratio and the predominant mode of failure for each specimen.

Figures 1 through 21 represent the circumferential and axial stress/strain curves for each sample. Also included on the figures is a summary of the sample's depth, orientation, tangent modulus and Poisson's ratio.

FAILURE CHARACTERISTICS

The predominant mode of failure was that of a double wedge or double cone configuration. These were accompanied by considerable axial splitting and slabbing which sometimes resulted in the failure of a strain gauge before the ultimate load was reached. Partially formed single diagonal failure planes were apparent in several samples although the explosive nature of the failures made it impossible to measure the angles.

ACKNOWLEDGEMENTS

The author would like to acknowledge the valuable assistance of Ms. Roseanna von Sacken during this test program.

REFERENCES

1. Lang, P. "Personal communication", 1985.
2. Annor, A. and Geller, L. "Dilatational velocity, Young's modulus, Poisson's ratio, uniaxial compressive strength and Brazilian tensile strength for WN1 and WN2 samples", CANMET/MRL Technical Data 303410-M01/78, 1978.
3. Lama, R.D., Saluja, S.S., Vutikuri, V.S. "Handbook on mechanical properties of rocks", Volume II, Chapter 7, Trans Tech Publications.

Table 1 - Summary of sample depth, dimensions, density and orientation

Drill hole	Sample depth (m)	Length (mm)	Diameter (mm)	Density (gm/cm^3)	Orientation α	Orientation β
206-010-MOD1	3.130	113.80	44.42	2.66	90°	0°
	3.185	112.66	44.44	2.64	90°	90°
	3.243	110.80	44.42	2.64	90°	45°
	3.425	110.84	44.40	2.64	135°	0°
	3.570A	108.54	44.32	2.64	135°	270°
	3.570B	90.16	44.40	2.63	0°	-
	3.570C	111.64	44.34	2.64	0°	-
	3.774	82.38	44.38	2.64	135°	270°
	3.892	112.16	44.42	2.63	135°	0°
	3.979	109.74	44.50	2.64	90°	315°
	4.048	108.56	44.50	2.63	90°	270°
	4.102	106.80	44.46	2.64	90°	0°
206-012-MOD1	4.017	108.64	44.36	2.63	90°	90°
	4.077	111.04	44.38	2.64	90°	60°
	4.137	111.44	44.40	2.64	90°	30°
	4.197	109.42	44.50	2.62	90°	0°
	4.212	109.00	44.34	2.64	60°	90°
	4.337	112.50	44.40	2.64	60°	0°
	4.342	118.40	44.40	2.63	30°	90°
	4.492	113.00	44.40	2.65	30°	0°
	4.912	113.82	44.24	2.65	90°	0°

Table 2 - Summary of ultrasonic velocity properties

Drill hole	Sample depth (m)	P-wave velocity(km/sec)	S-wave velocity(km/sec)	Dynamic shear modulus, G (GPa)	Dynamic Young's modulus, G (GPa)	Poisson's ratio (from velocity data)
206-010-M001	3.130	4.78	2.41	15.36	40.84	0.33
	3.185	3.87	2.40	15.20	36.10	0.19
	3.243	4.68	2.35	14.58	38.82	0.33
	3.425	4.55	3.42	30.87	52.51	-0.15
	3.570A	3.89	2.32	14.20	34.77	0.22
	3.570B	4.53	2.27	13.57	40.72	0.33
	3.570C	4.41	2.43	15.59	39.97	0.28
	3.774	3.92	2.11	11.75	30.47	0.30
	3.892	4.51	2.23	13.10	35.06	0.34
	3.979	4.23	2.05	11.09	29.87	0.35
	4.048	3.99	2.71	19.34	41.47	0.07
	4.102	5.02	2.66	18.64	48.65	0.30
206-012-M001	4.017	3.78	3.03	24.15	29.03	-0.40
	4.077	4.00	2.58	17.57	40.18	0.14
	4.137	4.44	2.31	14.08	37.02	0.31
	4.197	4.72	2.91	22.19	52.96	0.19
	4.212	3.61	2.75	19.99	32.33	-0.19
	4.337	4.70	2.84	21.25	51.54	0.21
	4.342	3.85	2.37	14.77	35.30	0.19
	4.492	4.37	2.41	15.37	39.40	0.28
	4.912	4.35	2.82	21.09	47.98	0.14

Table 3 - Summary of uniaxial compression properties

Drill hole	Sample depth (m)	Loading rate (MPa/sec)	Uniaxial compressive strength (MPa)	Tangent modulus of elasticity (GPa)	Secant modulus of elasticity (GPa)	Poisson's Ratio	Predominant failure characteristic
206-010-M001	3.130	0.65	174	68.99	57.81	0.24	double wedge
	3.185	0.73	215	64.50	45.05	0.23	double wedge
	3.243	0.86	164	67.33	57.80	0.26	double cone
	3.425	1.00	203	69.45	57.65	0.24	double cone
	3.570A	0.91	210	68.10	47.40	0.26	double wedge
	3.570B	0.92	185	64.94	50.55	0.23	double wedge
	3.570C	0.84	205	63.65	50.31	0.22	double wedge
	3.774	0.70	187	69.15	47.81	0.23	axial splitting
	3.892	0.78	168	65.01	51.18	0.24	bottom wedge
	3.979	0.83	165	66.85	54.60	0.20	bottom wedge
	4.048	1.07	204	71.55	49.65	0.24	double cone
	4.102	0.50	75	67.12	52.79	0.38	axial splitting
206-012-M001	4.017	0.72	192	61.81	42.33	0.21	double cone
	4.077	0.67	165	66.00	45.42	0.19	double cone
	4.137	0.81	184	65.37	53.47	0.20	double cone
	4.197	0.83	172	69.44*	54.36	0.29*	bottom cone
	4.212	0.80	189	63.56	41.74	0.19	double wedge
	4.337	0.89	179	62.51	51.58	0.23	double wedge
	4.342	0.93	198	59.91	44.45	0.29	bottom wedge
	4.492	0.51	75	40.22*	13.57*	N/A	axial splitting
	4.912	0.90	191	63.15	48.89	0.25	double wedge

*Properties were determined using LVDT measurements

APPENDIX A

Atomic Energy of Canada Limited
Research Company
Whiteshell Nuclear Research Establishment

L'Énergie Atomique du Canada, Limitée
Société de Recherche
Etablissement de Recherches Nucléaires de Whiteshell

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1985 September 4 AGB-85-374

Mr. Alfred Annor
CANMET
555 Booth Street
OTTAWA, Ontario
K1A 0G1

Dear Mr. Annor:

RE: TESTING OF DRILL CORE SAMPLES TO DETERMINE ANISOTROPIC PROPERTIES

The first drill core samples for anisotropic properties testing have been sent to you.

Figure 1 shows the location of the 200 mm sample hole in the URL lower shaft station.

Attachment 1 describes the system used for identifying and naming the individual 45 mm diameter cores and for describing their orientations with respect to the 200 mm core from which they were taken.

Attachment 2 describes how the 45 mm cores were taken from the 200 mm core samples.

We require testing of the samples, and interpretation of the results, to determine the anisotropic elastic constants and the true geographical orientation of the planes of anisotropy for the rock (see Reference). We would also like you to determine whether there is any anisotropy in the thermal properties. A bibliography of references that may be useful is attached.

We wish to acknowledge that this program of testing was suggested by Ram Jackson to replace the originally proposed, much more extensive and less conclusive method for obtaining this information.

If you have any further suggestions on how to carry out this program, especially with regard to the way the samples are collected, identified or number of samples required, please give me a call at (204) 345-8625.

cont'd . . ./2

It is anticipated that the next batch of samples will be sent in about 2 to 4 weeks. Thereafter samples will be sent at about 6 week intervals until 1986 August. We may have to send the 200 mm core samples for you to core out the 45 mm core samples because we do not have sufficient manpower at site. Also I expect you would prefer to see the whole sample to help with your interpretation and to ensure no mistakes in orienting the 45 mm cores.

Since coring this first batch of samples, I realized that we actually need 9 samples per core to determine the anistotropic properties. Therefore, in future the 200 mm cores will be about 900 mm long to provide enough sample for 9-45 mm cores from each 200 mm core.

REFERENCE

PERES-RODRIGUES, F. Anisotropy of granites. Modulus of elasticity and ultimate strength elipsoids, joint systems, slope attitudes and their correlations. Proc. 1st Cong. ISRM, Lisbon, V.I. pp.721-731.

Yours truly,

Peter Lang

P. A. Lang
APPLIED GEOSCIENCE BRANCH

PAL/pyc

cc: G. R. Simmons
S. H. Whitaker
P. M. Thompson

Attachments

BIBLIOGRAPHY

1. Amadei,B. 1982. The influence of Rock Anisotropy on Measurement of Stresses in-situ. Ph.D Thesis, University of California, Berkeley.

2. Amadei,B. and Goodman,R.E. 1981. Formula of Complete Plain Strain for Regularly Jointed Rocks. Proc. 22nd Symposium of Rock Mechanics (M.I.T.), pp.245-251.

3. Brace, Paulding, Scholz. 1966. Dilatency in the Fracture of Crystalline Rock. J. Geophys. Res. #71, 3939-3952.

4. Broch,E. 1974. The Influence of Water on some Rock Properties. Proc. 3rd Congress Int. Soc. Rock Mech., Denver, Vol 2 Part A, pp.276-398.

5. Crouch and Starfield,A.M. 1982. Boundary Element Methods in solid Mechanics with Applications in Rock Mechanics and Geological Eng. Univer. of Minnesota.

6. Coates,D.F. and CANMET, Energy Mines and Resources Canada. Rock Mechanic Principals. Canadian Government Publishing Centre, Hull, Quebec, 1981.

7. Costin,L.S. 1983. A Microcrack Model for the Deformation and Failure of Brittle Rock. J. Geophys. Res. Accepted 1983.

8. Costin,L.S. and Holocomb,D.J. A continuum model of inelastically deformed brittle rock based on the mechanics of microcracks. Proc. Int. Conf. on Constitutive Laws for Engineering Materials, Univ. of Arizona, Jan., 1983.

9. Costin,L.S. and Mecholsky,J.J. 1983. Time dependent Crack Growth and Failure in Brittle Rock. 24th U.S. Sysmp. Rock Mech., June, 1983.

10. Douglass,P.M. and Voight,B. 1969. Anisotropy of Granites; A Reflection of the Microscopic Fabric. Geotechnique 19, pp. 376-398.

11. Duncan and Goodman. 1968. Finite Element Analysis of Slopes in Jointed Rock. U.S. Army Corps of Engineers Report, TR# 1-68.

12. Everitt, Brown, Kerr, Bloomer. 1984. Preliminary Summary of Geologic Data Collected on Interval 275m to 239m AMSL, URL Shaft, AECL, Lac du Bonnet, Manitoba.

13. Eissa,E.S.A. 1980. Stress Analysis of Underground Excavations in Isotropic and Stratified Rock using The Boundary Element Method. PhD. Dissertation, Imperial College, London.

14. Goodman,R.E. and Taylor,R.L. and Brekke,T.L. 1968. A Model for the Mechanics of Jointed Rock. Journal of the Soil Mech. and Foundation Division. ASCE. Vol 94, #3M3, pp.637-659.

15. Goodman,R.E. 1976. Methods of Geological Engineering. West Publ.

16. Halleck,P. and Kumnick,A.J. 1980. The Influence of Orientation of Fracture Toughness and Tensile Moduli in Berkeley Granite. The State of the Art in Rock Mechanics, Proc. of the 21st U.S. Symp., Rolla,M.O., May 30, 1980.

17. Hearmon,R.F.S. 1961. An Introduction to Anisotropic Elasticity. Oxford Univ. Press, 136 pp.

18. Kipp,M.E., Grady,E. and Chen,E.P. 1980 Strain rate dependent fracture initiation. Int. J. Fracture, 16, p. 471.

19. Likhnitskii,S.G. 1963. Theory of elasticity of an anisotropic elastic body. Holden, Inc. San Francisco.

20. Morland,L.W. 1976. Elastic Anisotropy f Regularly Jointed Media. Rock Mechanics, v.8 pp.35-48.

21. Nishihara, M. 1957. Stress-Strain Relation of Rocks. Doshisha Engng Rev. #8, pp.32-54.

22. Ove Alm. 1982. Effect of Water on Mechanical Properites. Proc. 23rd Symp. on Rock Mechanics, Society of Mining Engineers of the American Inst., N.Y., N.Y., U.S.A., pp.261-269.

23. Peres-Rodrigues,F. 1966. Anisotropy of granites. Modulus of Elasticity and Ultimate Strength Ellipsoids, Joint Systems, Slope Attitudes and their Correlations. Proc. 1st Cong. ISRM, Lisbon, V.1, pp.721-731.

24. Peres-Rodrigues,F. 1970. Anisotropy of Rocks. Most probable surfaces of the Ultimate Stresses and of the Moduli of Elasticity. Proc. 2nd Cong. ISRM, Belgrade, V.1, 1-20.

25. Scholz,C. 1970. The Rosle of Microfracturing in Rock Deformation. Proc. 2nd Cong. ISRM, Belgrade, v.1, 2-8.

26. Singh,B. 1973. Continuum characterization of Jointed Rock Masses. Int. J. Rock Mech. Min Sci, V.10, #4, pp.311-335.

27. Tullis,J., and Yund,R.A. 1980. Hydrolytic Weakening of Experimentally Deformed Westerly Granite and Hale Albite. J. Struct. Geol., v.2, pp.439-451.

28. Yaffe,D.C., Byers,D.H., and Hosey,D.A. 1956. Encyclopedia of Instrumentation for Industrial Hygiene. Univer. of Michigan, Inst. of Industrial Health, Ann Arbor, Michigan, pp.536-537;1200-1202.

29. Zienkiewicz,O. Valliappan,S. and King,I. 1968. Stress analysis of rock as a 'no-tension material. Geotechnique, 18, pp.56-66.

DESIGNATION OF ANISOTROPIC PROPERTIES SAMPLES

The location and orientation of the 200 mm diameter core hole number 206-010-MOD1 is as follows:

Collar Coordinates	: N 5,570,460.232
	E 295,789.288
	elev. 52.905
Orientation	: Plunge (dip): -0.6° (up)
	: Trend (direction): 025°

The location and orientation of the 45 mm cores taken from the 200 mm cores is shown on Figure 1 to 3 and defined as follows:

a) depth of the collar of the 45 mm hole from the collar of the 200 mm hole

b) angle β gives the location of the collar of the 45 mm hole around the circumference of the 200 mm core. The angle is measured clockwise (looking down hole) from the orientation mark on the top of the core.

c) angle α is the angle between the core axis of the 45 mm core and the 200 mm core. The angle is measured clockwise (i.e. dip) from the down hole direction of the 200 mm core.

The depth, and α and β angles are marked on each core, and on a label on water proof paper attached to each core. They are also listed in Table 1 and 2 of Attachment 2.

In addition to these markings, there is a line and an arrow on the collar end of each 45 mm core (except the axial core). The line indicates the axial direction of the 200 mm core and the arrow points down hole. The short line across the axial line indicates the point at which the depth is measured. The 45 mm cores that are parallel to the 200 mm core axis, contain the axial line and arrow marked along the top of the core.

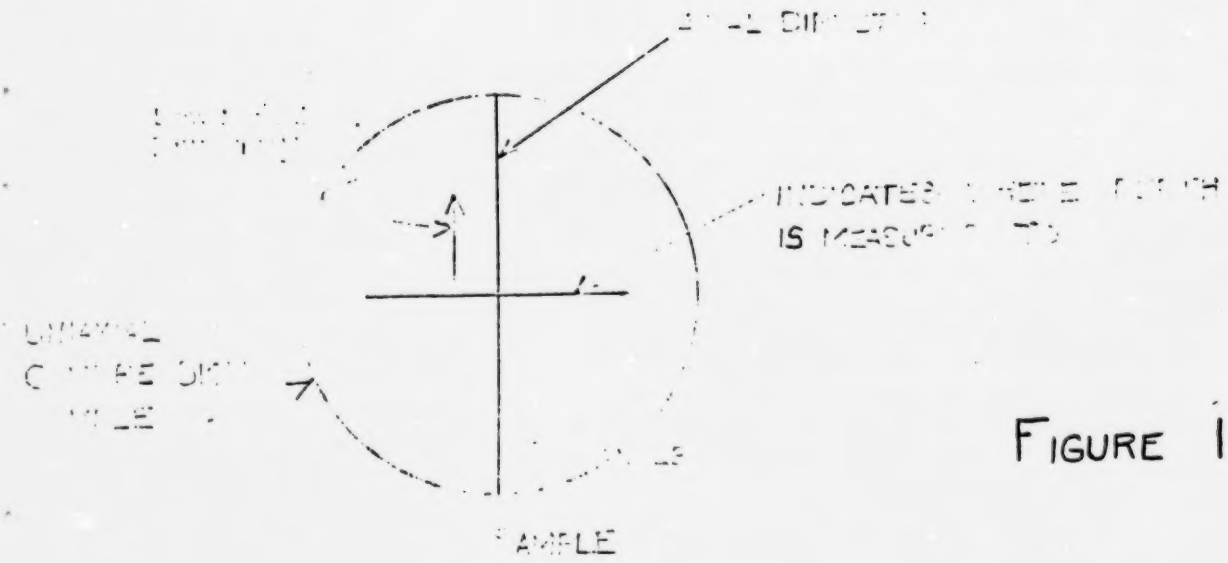


FIGURE 1

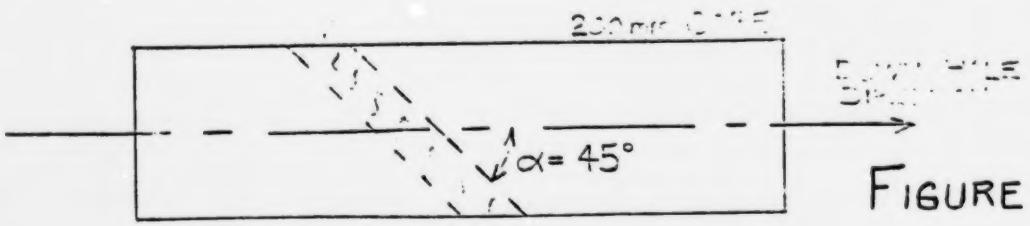


FIGURE 2

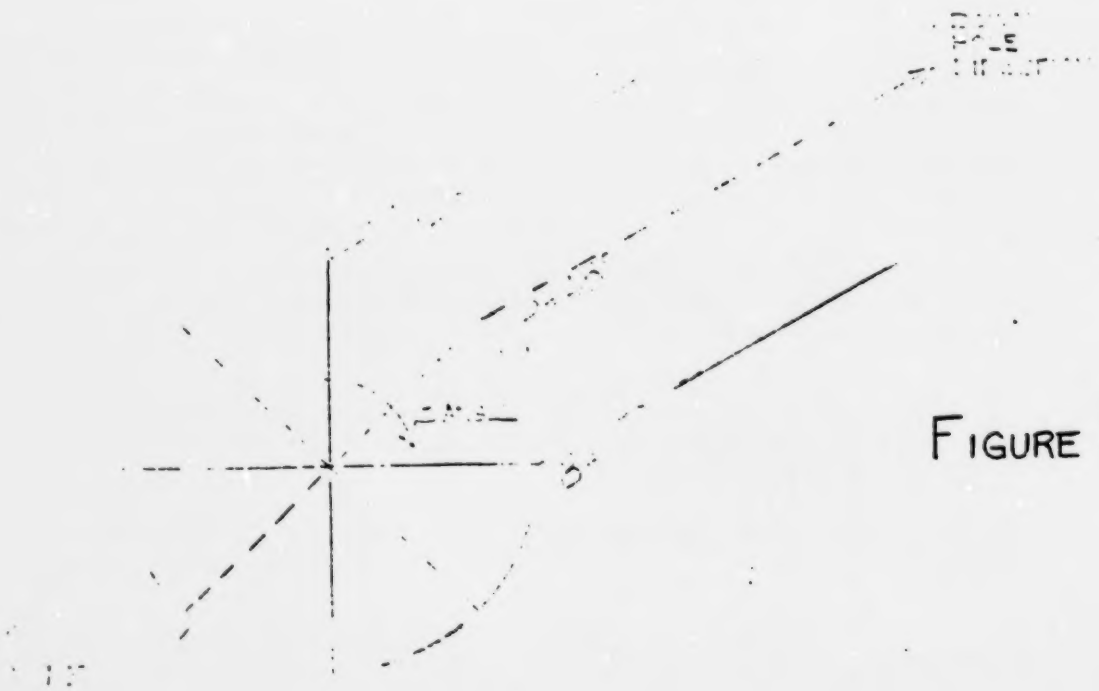


FIGURE 3

ANISOTROPIC PROPERTIES SAMPLES

AIM: To drill out 6 45 mm diameter core samples from a piece of 200 mm diameter core. Two pieces of 200 mm diameter core were available from hole No. 206-010-MOD1. The 45 mm core samples will be sent to CANMET, cut to suitable length and tested to determine the anisotropic elastic properties and to determine if there is any anisoptropy in the thermal properties.

MATERIALS + EQUIPMENT:
- type and model No. ?Longyear Diamond Drill
- two 200 mm core sample each 580 mm in length
- Brunton compass
- 52 mm OD, 45 mm ID Diamond drill bit
- lumber to secure core and drill (see Figure C1)
- chains to secure core

PROCEDURE: The diamond drill was set up and secured by screwing it into the floor with a star shield and threaded bolt. The locations for the collars of the 45 mm core sample holes were drawn on the 200 mm core. The holes were laid out to obtain cores in the six directions shown on Fig. 2. The order of drilling the samples was selected carefully to make the best use of the available length of core.

The position of the 45 mm sample cores was defined by using 3 parameters:

1) Depth along the 200 mm core, depth measured from hole collar.
2) Angle around the circumference taking 0° at the top of the core (β angle).
3) Angle of the 45 mm diameter core from the axial direction of the 200 mm core (α angle).

To measure the β angle, a circumferential protractor was made using a piece of mylar and dividing the circumference of the 200 mm diameter core into 45° increments. These 3 positioning parameters were set up in a table and each core labelled with all information with a permanent marker. The information was also written on a piece of waterproof paper tied on with wire.

Before each sample was drilled, the axial direction and corresponding β angle were marked on the top of the 45 mm core. An arrow on the top of each 45 mm core points towards the bottom of the 200 mm hole.

Most of the samples were approximately 195 mm in length with the axial sample being about 110 mm. For the cores with α = 45°, the brunton compass was used to align the moveable diamond drill at the proper angle.

The available data on the drill bit used is recorded in Table 3.

OBSERVATIONS: The drilling went quite well and took 3 days (~ 18 hours). In one case, the drilling of one sample touched another hole and made the sample no good. This sample was re-drilled.

CONCLUSIONS: All of the samples have $\geq$ 110 mm of useable core and should allow enough core for grinding to the proper size for uniaxial compression testing.

TABLE 1

DRILL HOLE No. 206-010-MOD1
2.99 to 3.57

DEPTH (m)	α (From Axial)	β (Around Circumference)	DATE DRILLED
3.130	90°	0°	85-08-13
3.185	90°	90°	85-08-13
3.243	90°	45°	85-08-13
3.425	135°	0°	85-08-16
3.570	135°	270°	85-08-16
3.570	0°	—	85-08-16

TABLE 2

DRILL HOLE No. 206-010-MOD1
3.57 m to 4.15 m
MARK TOP OF HOLE AND AXIAL DIRECTIONS

DEPTH (m)	α (From Axial)	β (Around Circumference)	DATE DRILLED
4.102	90°	0°	85-08-12
4.048	90°	270°	85-08-12
3.979	90°	315°	85-08-12
3.892	135°	0°	85-08-12
3.961+	135°	270°	85-08-13
3.774	135°	270°	85-08-13
3.570	0°	—	85-08-13

+ This sample had to be redrilled.

TABLE 3

INFORMATION ON DRILL AND DRILL BIT

Longyear

OD = 51 mm
ID - 45 mm

Core Barrel Length = 310 mm

- No visible Serial Number

- Artifical Diamonds

DRILL S/N C5766

DIAMOND DRILLER - Gerry Sachvie

SUPERVISOR - Henry Wojciechowski
- Stn 51 2208

FIGURE #1

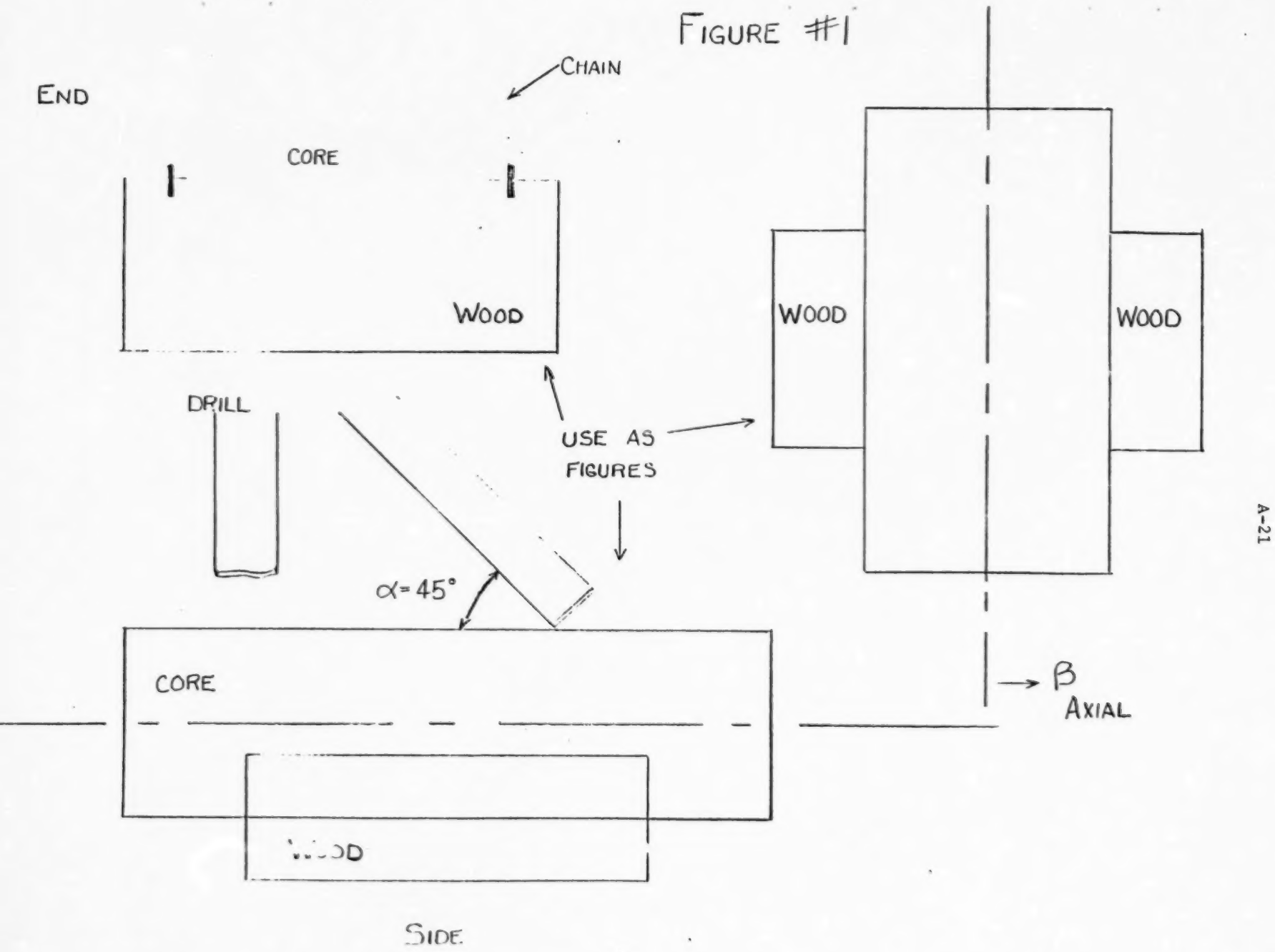
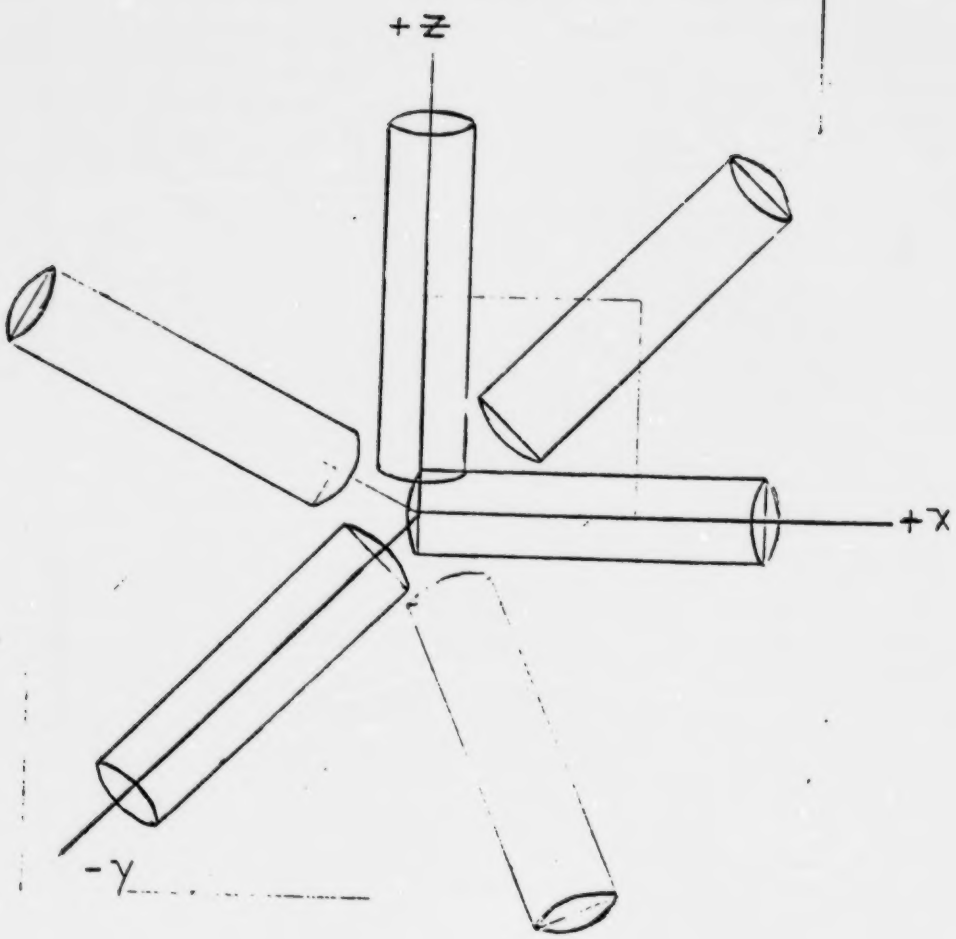
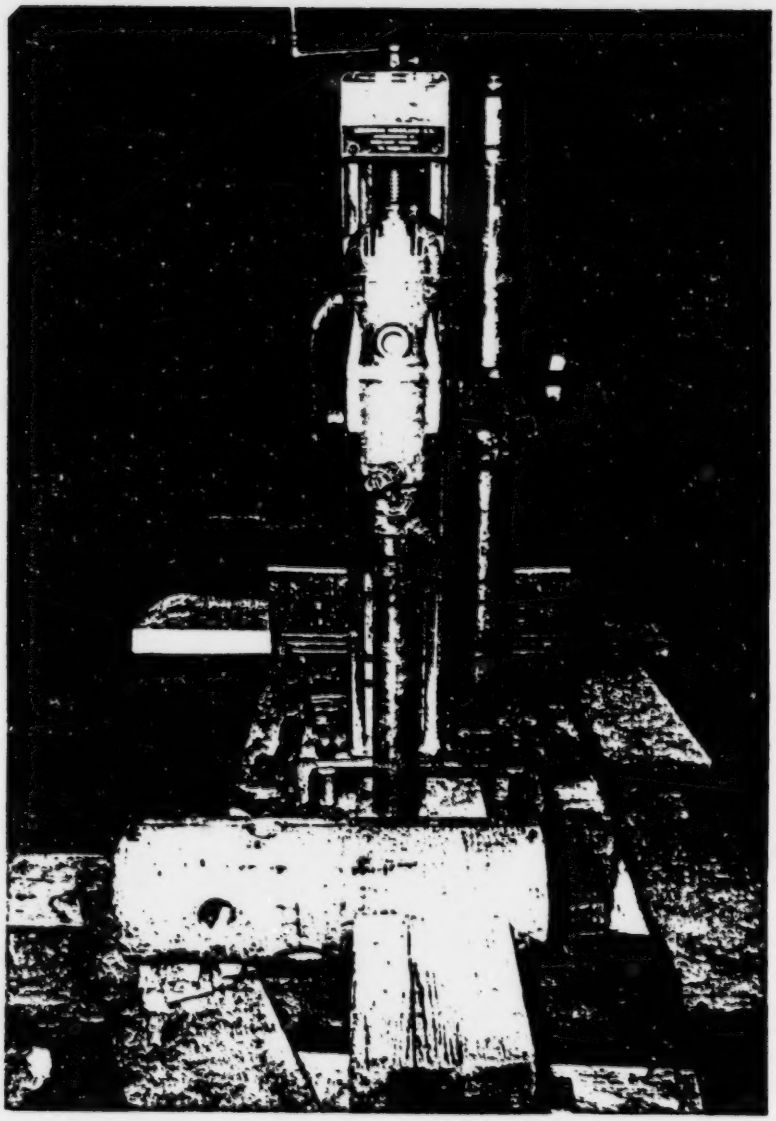
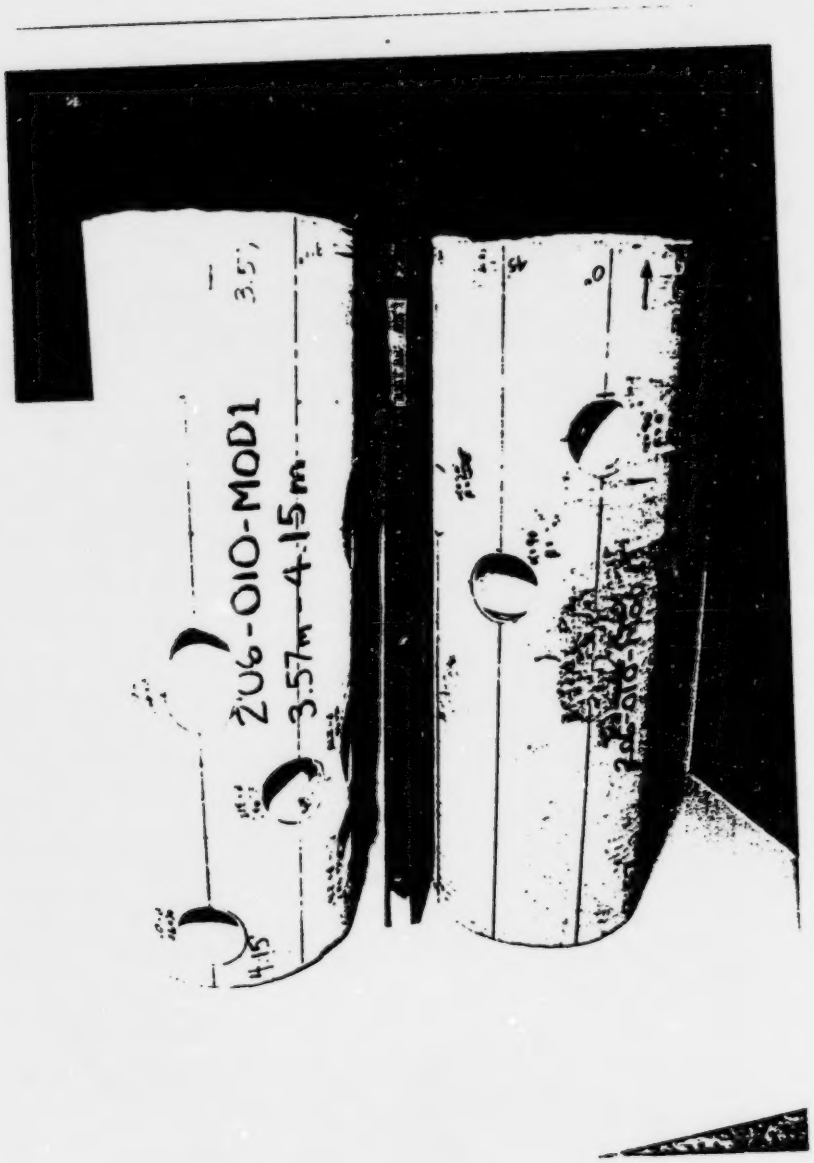

END
CHAIN
CORE
WOOD
DRILL
USE AS
FIGURES
WOOD
WOOD
α = 45°
CORE
B
AXIAL
WOOD
SIDE

FIGURE #2 A-22



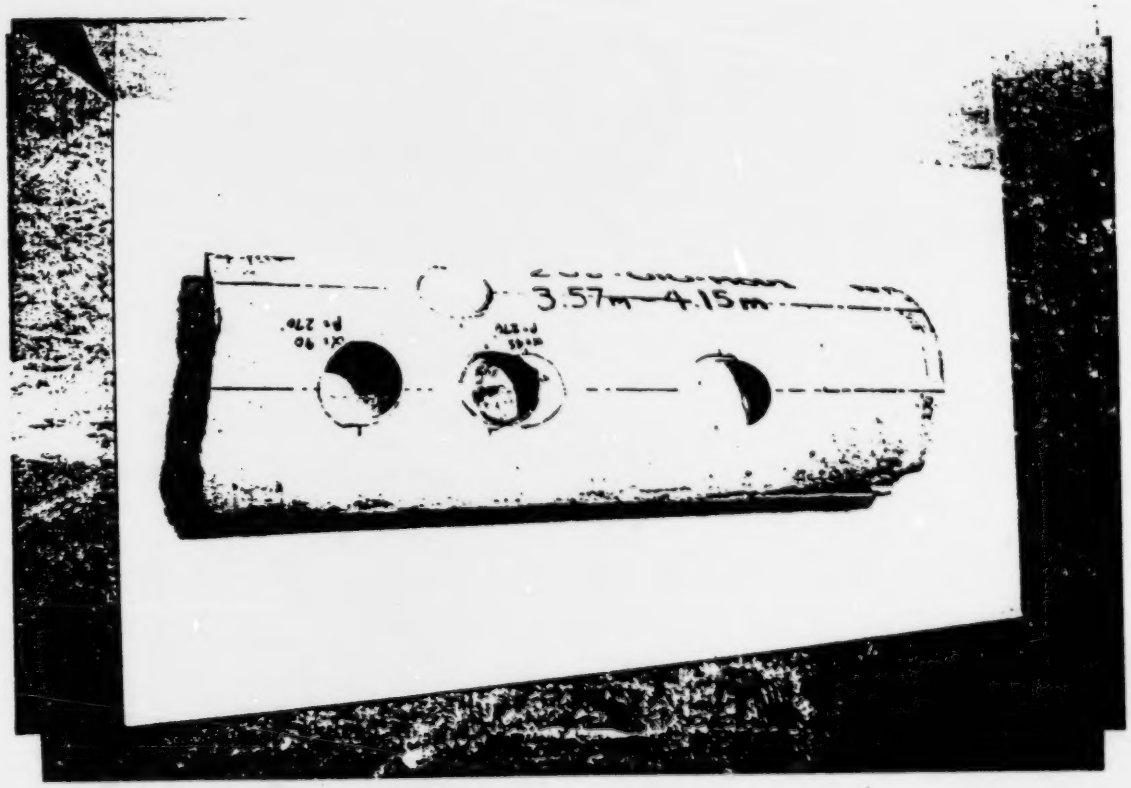


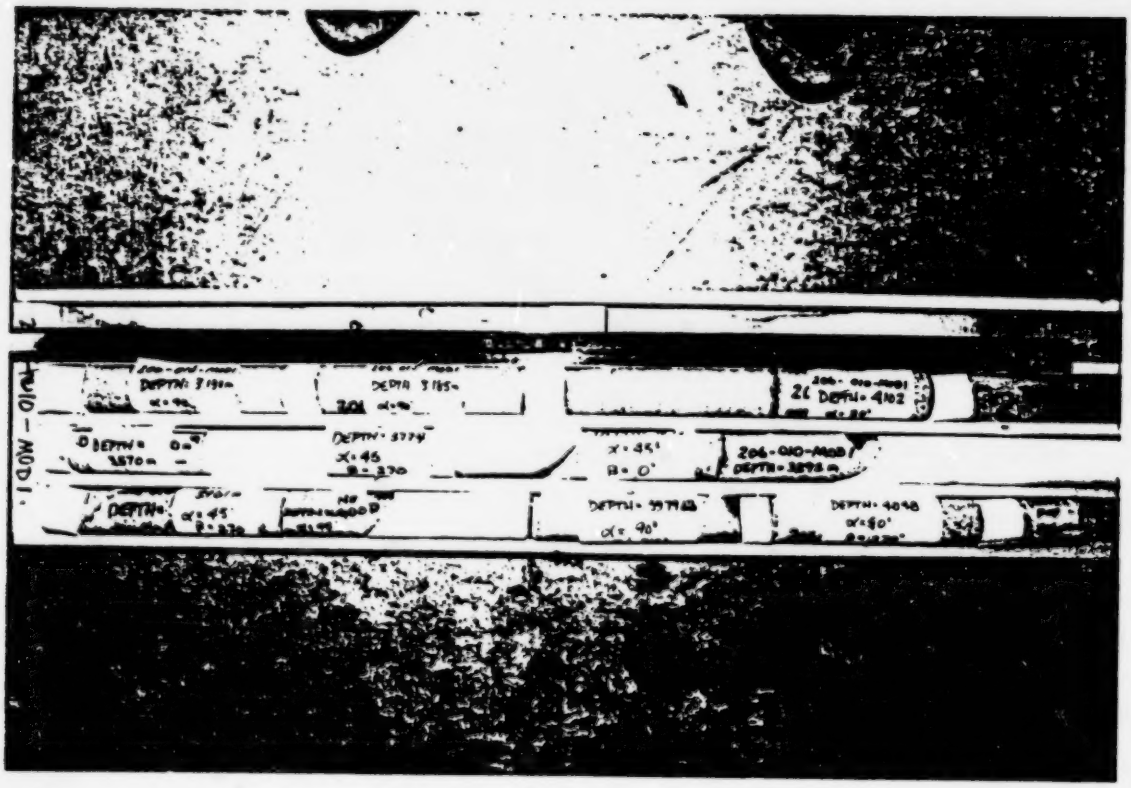
GOODYEAR DIAMOND DRILL SET-UP
OVER 200 mm DIAMETER CORE



2 200 mm DIAMETER CORES SHOWING ANISOTROPIC PROPERTY SAMPLES DRILLED CUT AT VARIOUS ANGLES
HOLE # IS 206-010-MOD1

206-010-MOD1
3.57m-4.15m


3.57m-4.15m



ANISOTROPIC PROPERTY SAMPLES SHOWING DEPTHS, X, AND B angles IN CORE BOX READY TO SHIP TO CANMET

Atomic Energy of Canada Limited
Research Company
Whiteshell Nuclear Research Establishment

L'Énergie Atomique du Canada, Limitée
Société de Recherche
Etablissement de Recherches Nucléaires de Whiteshell

Pinawa
Manitoba
Canada
R0E 1L0
(204) 753-2311
Telex 07-57553
Twx 610-672-8141

APPLIED GEOSCIENCE BRANCH 1985 October 02 AGB-85-416

Mr. Alfred Annor
CANMET
555 Booth Street
OTTAWA, Ontario
K1A 0G1

Dear Alfred:

The second batch of anisotropic properties samples will be sent to you this week. This batch consists of 9 samples from one 200 mm core from drill hole 206-012-MOD1.

The attachments give the details of the 200 mm drill hole location, methods of coring out the 9 - 45 mm samples, the system for describing the 45 mm core location and orientation, and photographs of the samples. A copy of the paper by Rodrigues is also attached.

Please note that there is an error in the coordinates given in Attachment 1 of my previous memo. The Easting of drill hole 206-010-MOD1 is 295,798.288.

If you have any questions, please call me at (204) 345-8625.

Yours truly,

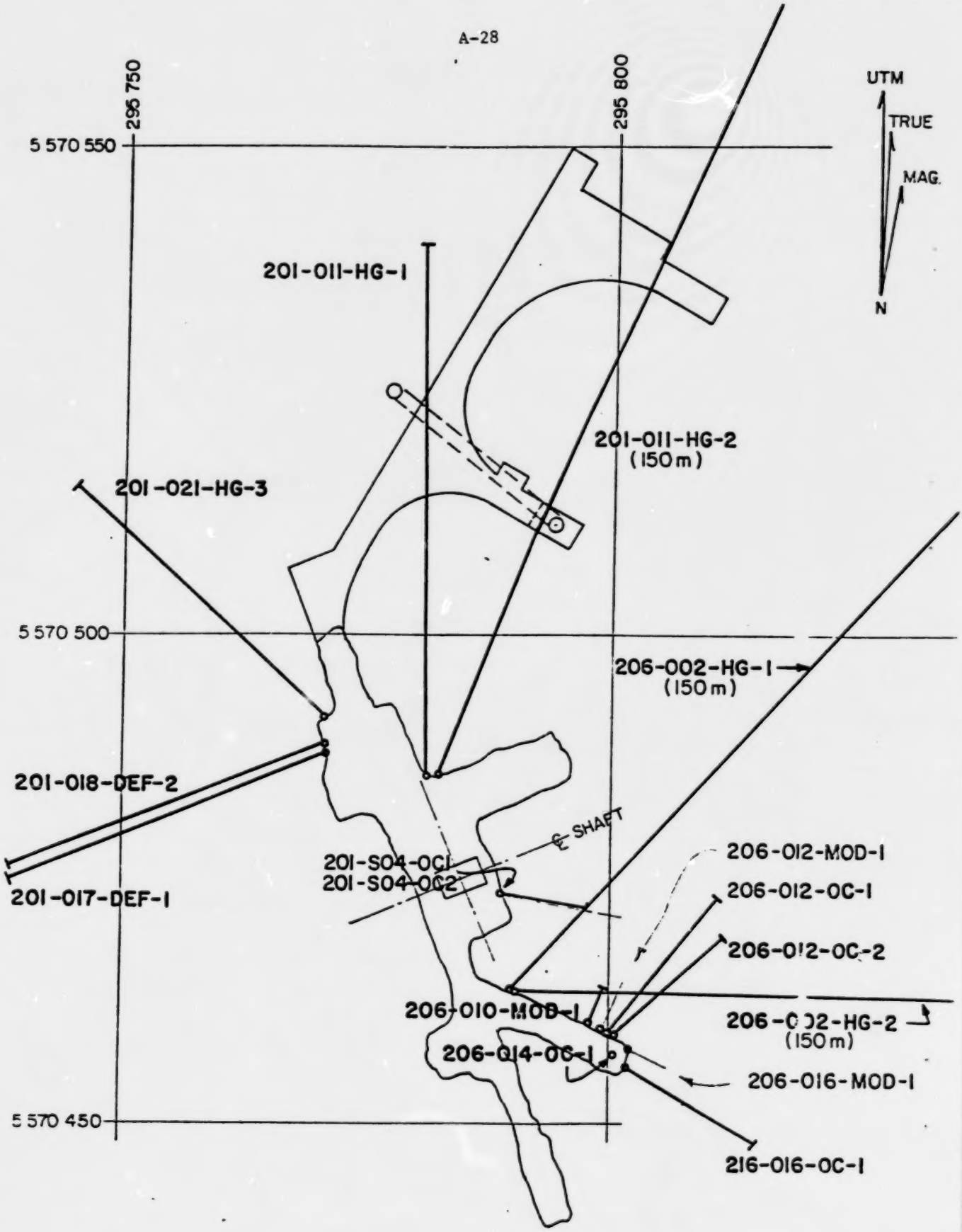
Peter Lang

P. A. Lang
Applied Geoscience Branch

PAL:odt

Attachments

cc: P. M. Thompson
G. R. Simmons
S. H. Whitaker
S. Daley


295 750
295 800
5 570 550
5 570 500
5 570 450
UTM
TRUE
MAG.
N
201-011-HG-1
201-011-HG-2
(150 m)
201-021-HG-3
206-002-HG-1
(150 m)
201-018-DEF-2
201-017-DEF-1
℄ SHAFT
201-S04-OC1
201-S04-OC2
206-012-MOD-1
206-012-OC-1
206-012-OC-2
206-010-MOD-1
206-002-HG-2
(150 m)
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206-016-MOD-1
216-016-OC-1

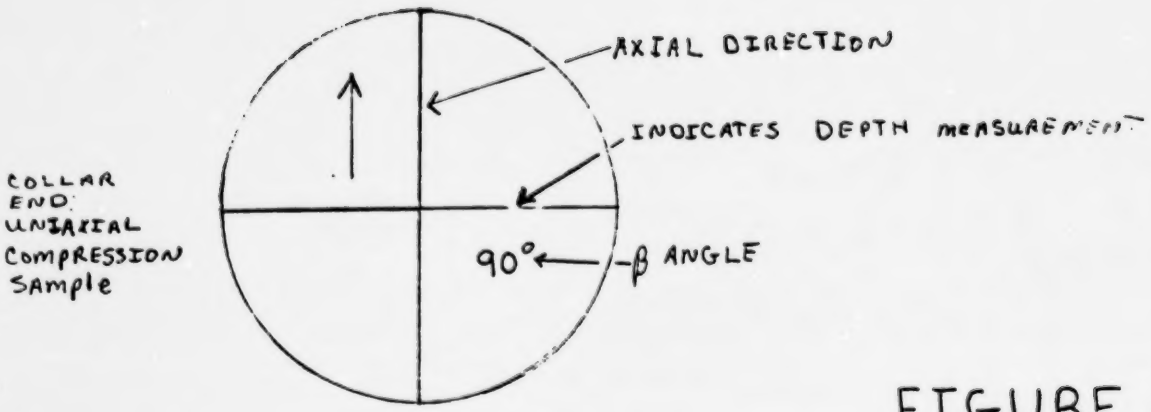


FIGURE 1

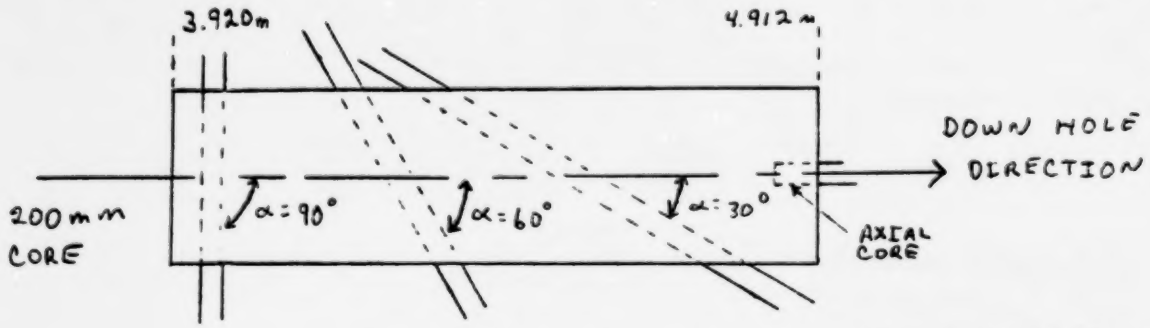


FIGURE 2

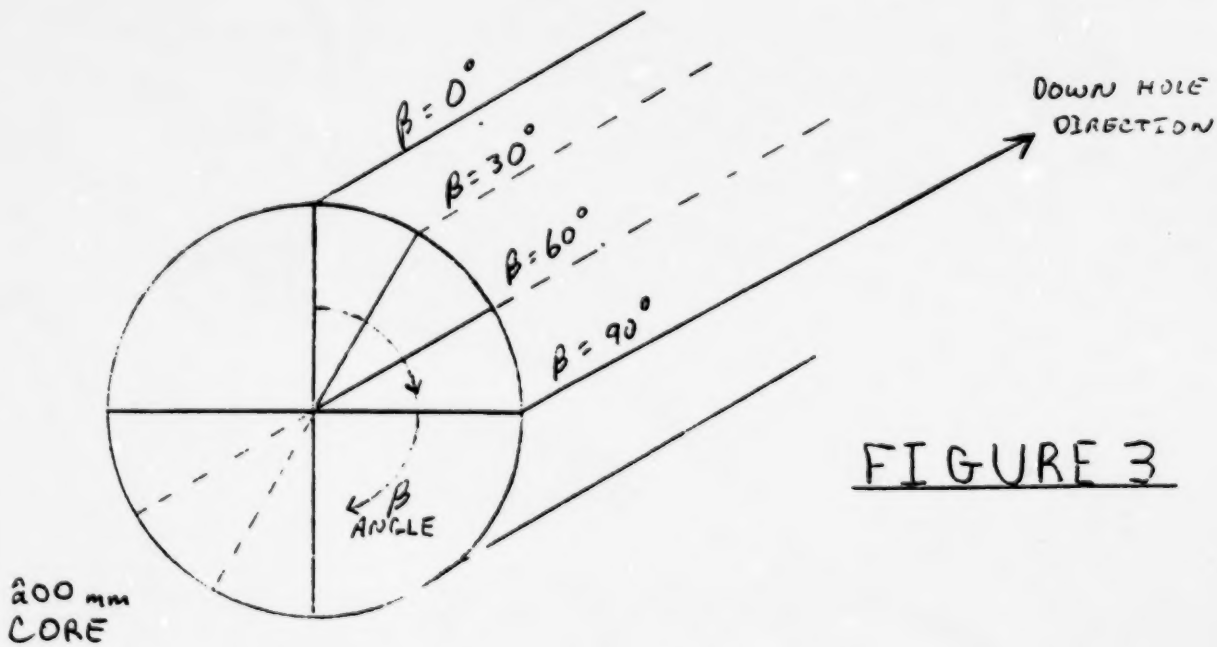


FIGURE 3

DESIGNATION OF ANISOTROPIC PROPERTIES SAMPLES

The location and orientation of the 200 mm diameter core hole number 206-012-MOD1 is as follows:

Collar Coordinates	:	N 5,570,459.711
		E 295,799.653
		elev. 53.186
Orientation	:	Plunge (dip): -02.51° (up)
	:	Trend (direction): 024.16°

The location and orientation of the 45 mm cores taken from the 200 mm cores is shown on Figure 1 to 3 and defined as follows:

a) depth of the collar of the 45 mm hole from the collar of the 200 mm hole

b) angle β gives the location of the collar of the 45 mm hole around the circumference of the 200 mm core. The angle is measured clockwise (looking down hole) from the orientation mark on the top of the core.

c) angle α is the angle between the core axis of the 45 mm core and the 200 mm core. The angle is measured clockwise (i.e. dip) from the down hole direction of the 200 mm core.

The depth, and α and β angles are maked on each core, and on a label on water proof paper attached to each core. They are also listed in Table 1 of Attachment 2.

In addition to these markings, there are two lines, an arrow, and β angle on the collar end of each 45 mm core (except the axial core). One line indicates the axial direction of the 200 mm core and the arrow points down hole. The other line across the axial line indicates the point at which the depth is measured. The 45 mm core that is parallel to the 200 mm core axis, contains the axial line and arrow marked along the top of the core.

Steve Daley
85-10-3

ANISOTROPIC PROPERTIES SAMPLES

AIM: To drill out 9 45 mm diameter core samples from a piece of 200 mm diameter core. One piece of 200 mm diameter core was available from hole No. 206-012-MOD1. The 45 mm core samples will be sent to CANMET, cut to suitable length and tested to determine the anisotropic elastic properties and to determine if there is any anisoptropy in the thermal properties.

MATERIALS + EQUIPMENT:
- Longyear Diamond Drill
- 200 mm core sample 992mm in length
- Stabila angle rule
- C clamp
- Longyear Industrial Diamond drill bit
- lumber to secure core and drill (see Figure No. 1)
- chains to secure core

PROCEDURE: The diamond drill was set up and secured by screwing it into the floor with a star shield and threaded bolt. The locations for the collars of the 45 mm core sample holes were drawn on the 200 mm core. The holes were laid out to obtain cores in the nine directions shown on Fig. 1, page 722 of attached report, Anisotropy of Granites. The order of drilling the samples was selected carefully to make the best use of the available length of core.

The position of the 45 mm sample cores was defined by using 3 parameters:

1) Depth along the 200 mm core, depth measured from hole collar.
2) Angle around the circumference taking 0° at the top of the core (β angle).
3) Angle of the 45 mm diameter core from the axial direction of the 200 mm core (α angle).

To measure the β angle, a circumferential protractor was made using a piece of mylar and dividing the circumference of the 200 mm diameter core into 30° increments. These 3 positioning parameters were set up in a table and each core labelled with all information with a permanent marker. The information was also written on a piece of waterproof paper tied on with wire.

Before each sample was drilled, the axial direction and corresponding β angle were marked on the top of the 45 mm core. An arrow on the top of each 45 mm core points towards the bottom of the 200 mm hole.

Most of the samples were approximately 195 mm in length with the axial sample being about 150 mm. For the cores with α = 60° and 30° the angle rule compass was used to align the moveable diamond drill at the proper angle.

The data on the drill and drill bit used is recorded in Table 3.

OBSERVATIONS: The drilling went well and took 2 days (~ 16 hours, including 2 hours for set up).

CONCLUSIONS: All of the samples have $\geq$ 110 mm of useable core and should allow enough core for grinding to the proper size for uniaxial compression testing.

Steve Daley
85-10-3

TABLE 1

DRILL HOLE No. 206-012-MOD1
3.920 to 4.912
MARK TOP OF HOLE AND AXIAL DIRECTIONS

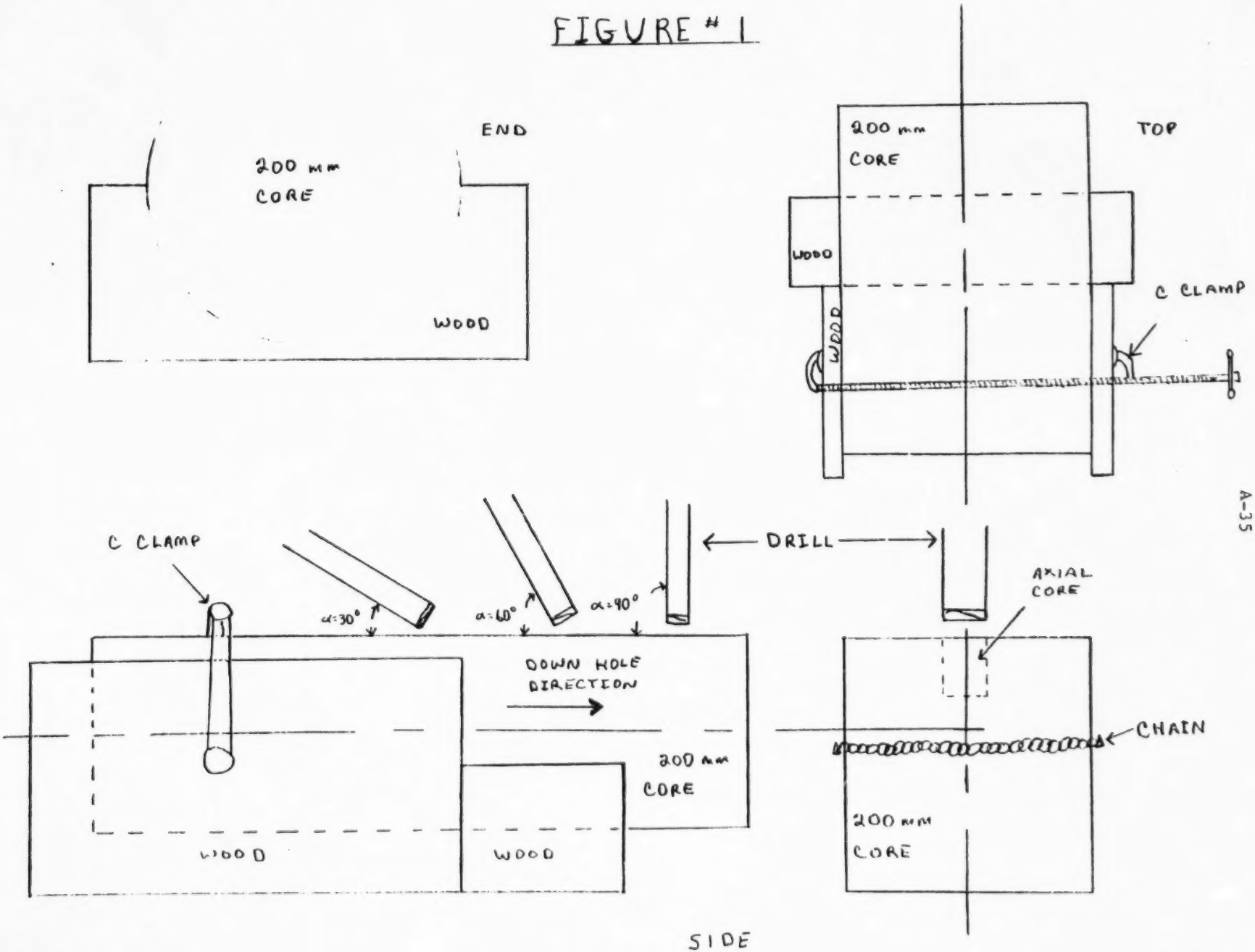
DEPTH (m)	α (From Axial)	β (Around Circumference)	DATE DRILLED
4.017	90°	90°	85-09-18
4.077	90°	60°	85-09-18
4.137	90°	30°	85-09-18
4.197	90°	0°	85-09-18
4.212	60°	90°	85-09-17
4.337	60°	0°	85-09-17
4.342	30°	90°	85-09-17
4.492	30°	0°	85-09-17
4.912	0°	Axial core	85-09-16

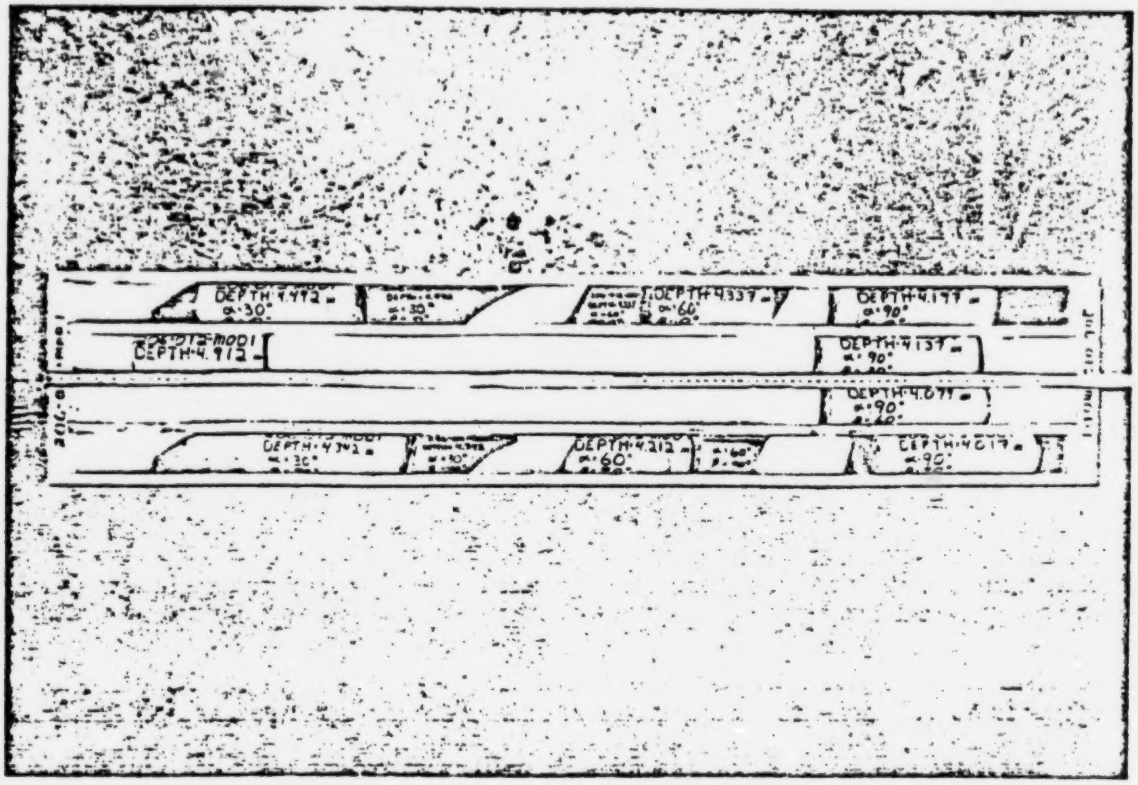
TABLE 3

INFORMATION ON DRILL AND DRILL BIT

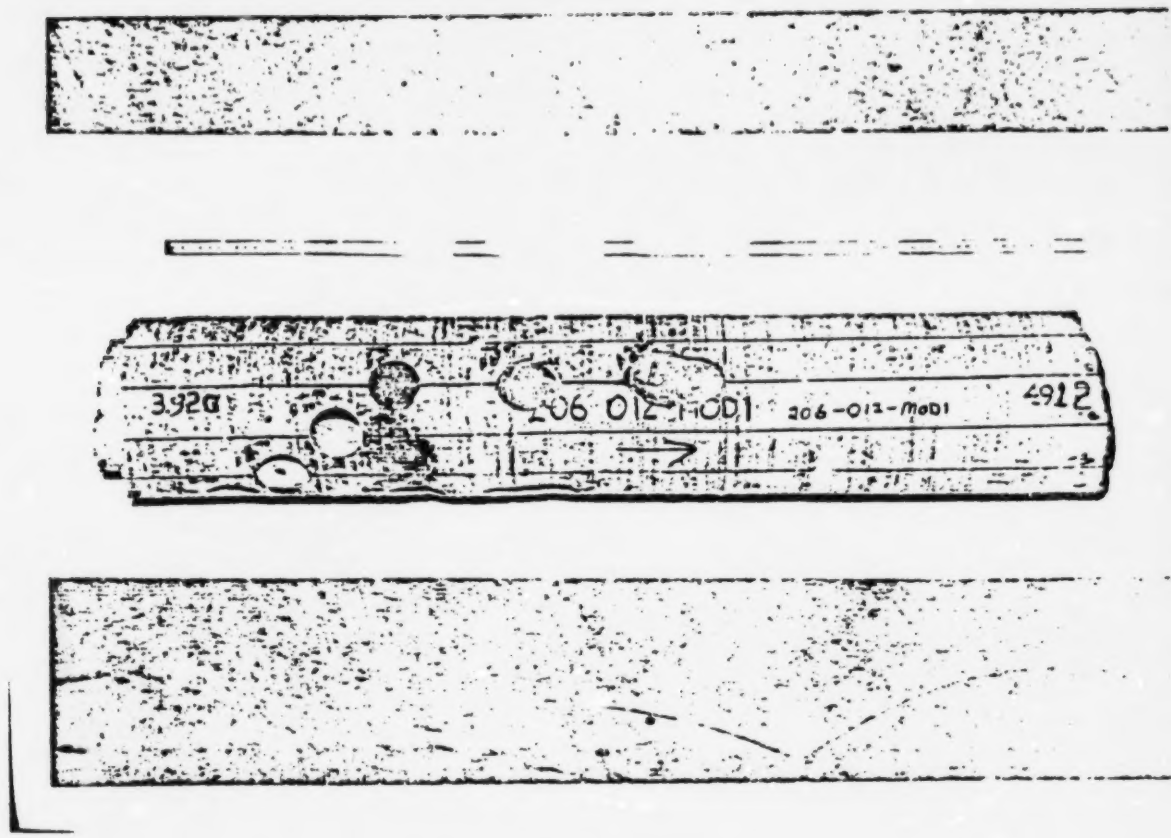
DIAMOND DRILLER	- Gerry Sachvie
SUPERVISOR	- Henry Wojciechowski - Stn 51 2208
LONGYEAR DIAMOND DRILL	- Model No. 330E - S/N C5766
LONGYEAR INDUSTRIAL DIAMOND DRILL BIT	- Model No. 5A2000 complete with solid back end - OD = 51 mm - ID = 45 mm - Core barrel length = 310 mm

FIGURE # 1

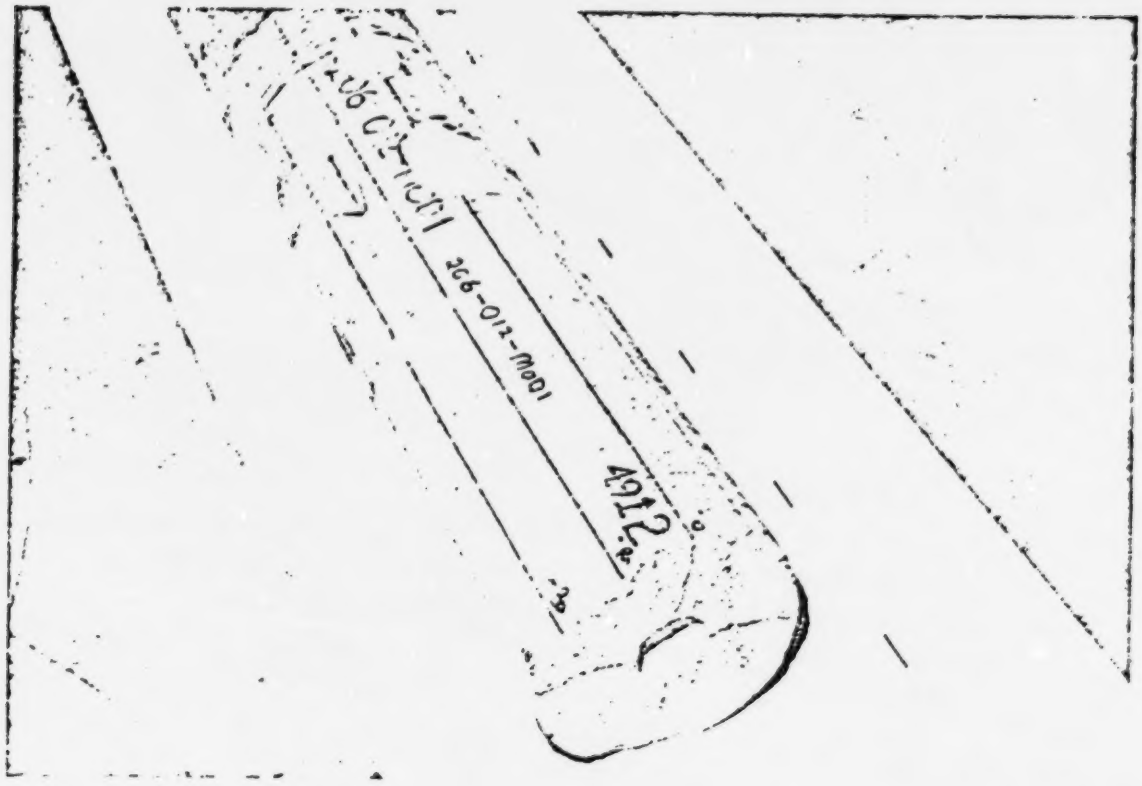

END
200 mm
CORE
WOOD
TOP
200 mm
CORE
WOOD
WOOD
C CLAMP
C CLAMP
α=30°
α=60°
α=90°
DRILL
AXIAL
CORE
DOWN HOLE
DIRECTION
CHAIN
200 mm
CORE
WOOD
WOOD
200 mm
CORE
SIDE

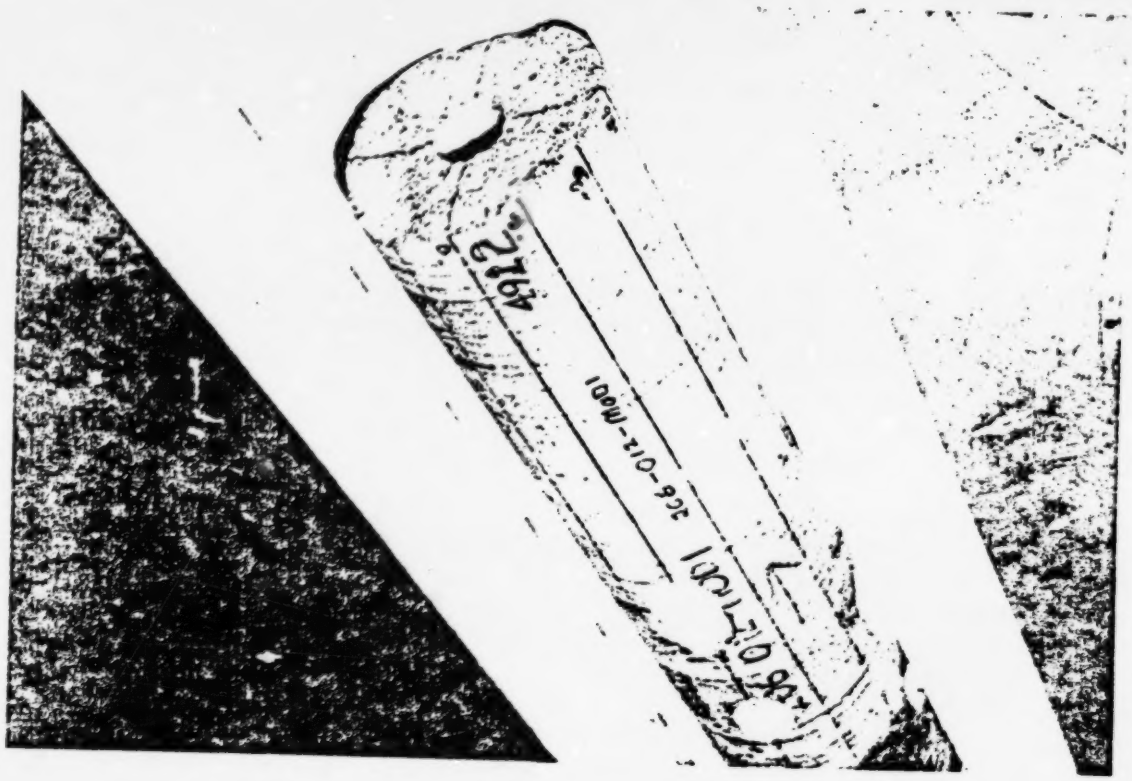


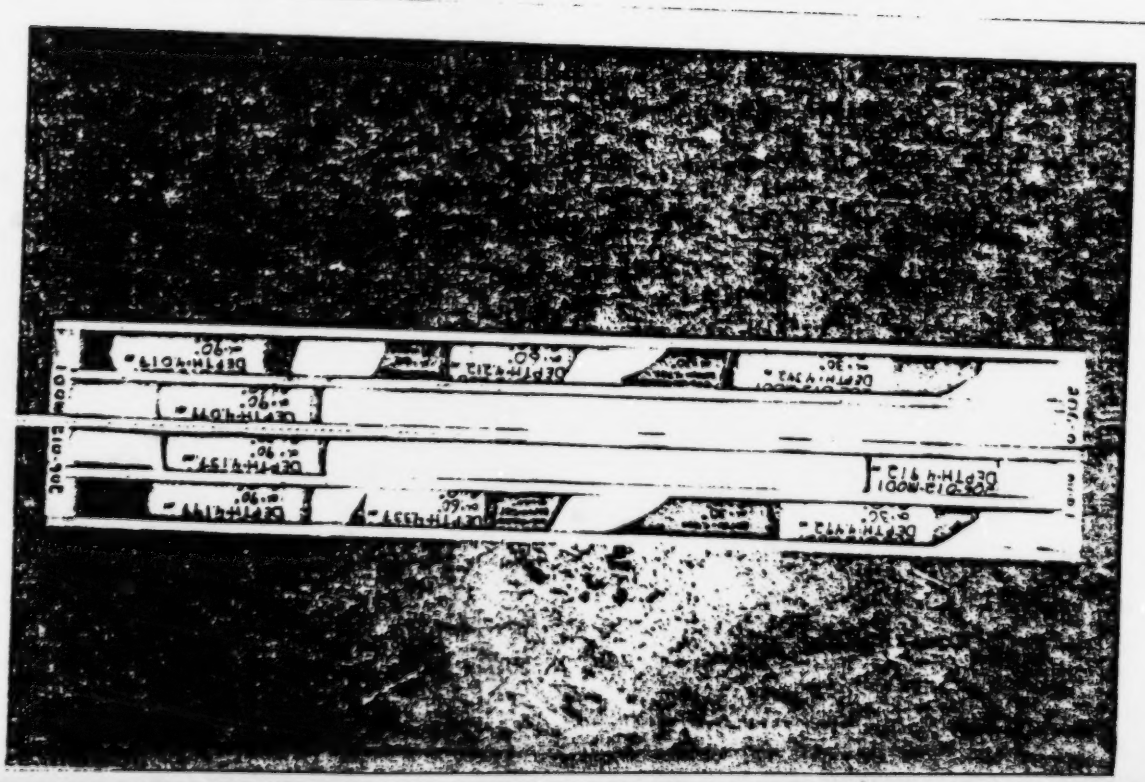
Anisotropic Property Samples Showing Depths, α, And β Angles In Core Box Ready To Ship To Cannet.

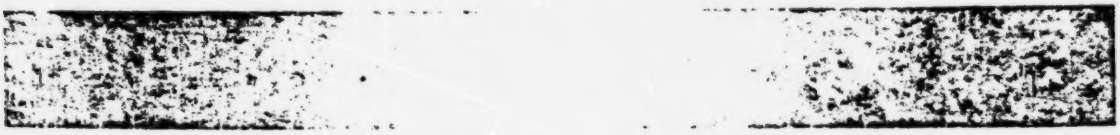


200 mm Diameter Core Showing Anisotropic property Samples Drilled out at Various Angles.

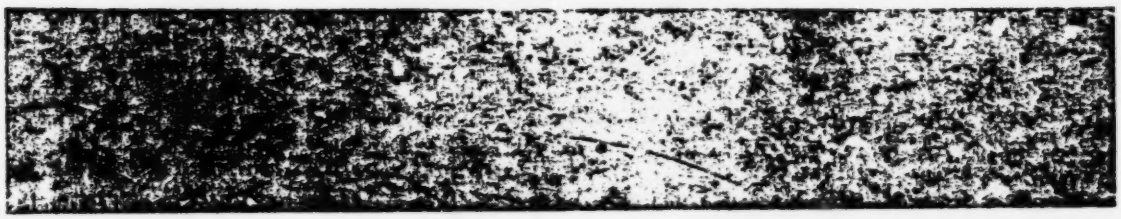

266-012-11001
4912

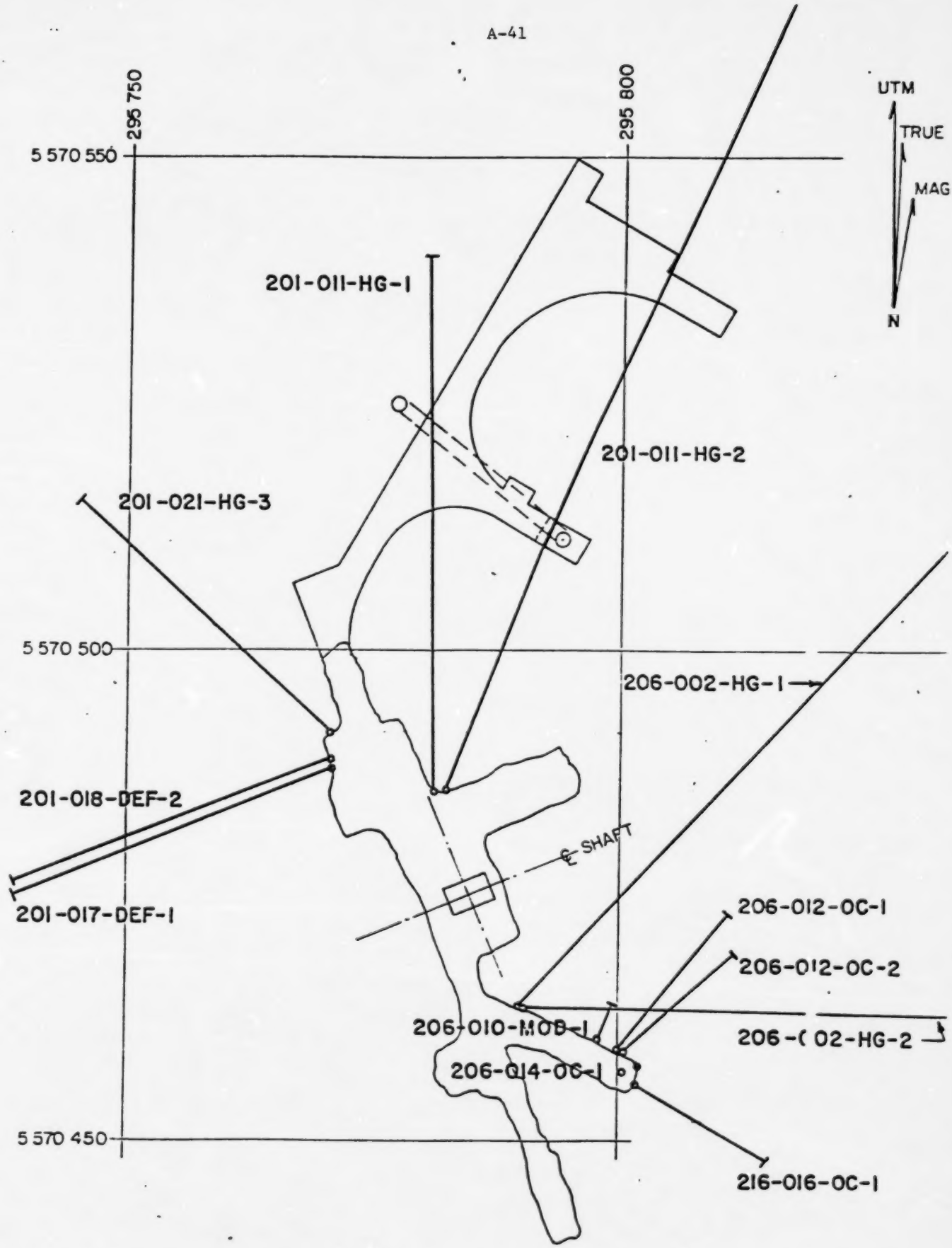






206 012 M001
206-012-M001
4912




295 750
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5 570 500
5 570 450
UTM
TRUE
MAG
N
201-011-HG-1
201-011-HG-2
201-021-HG-3
206-002-HG-1
201-018-DEF-2
201-017-DEF-1
℄ SHAFT
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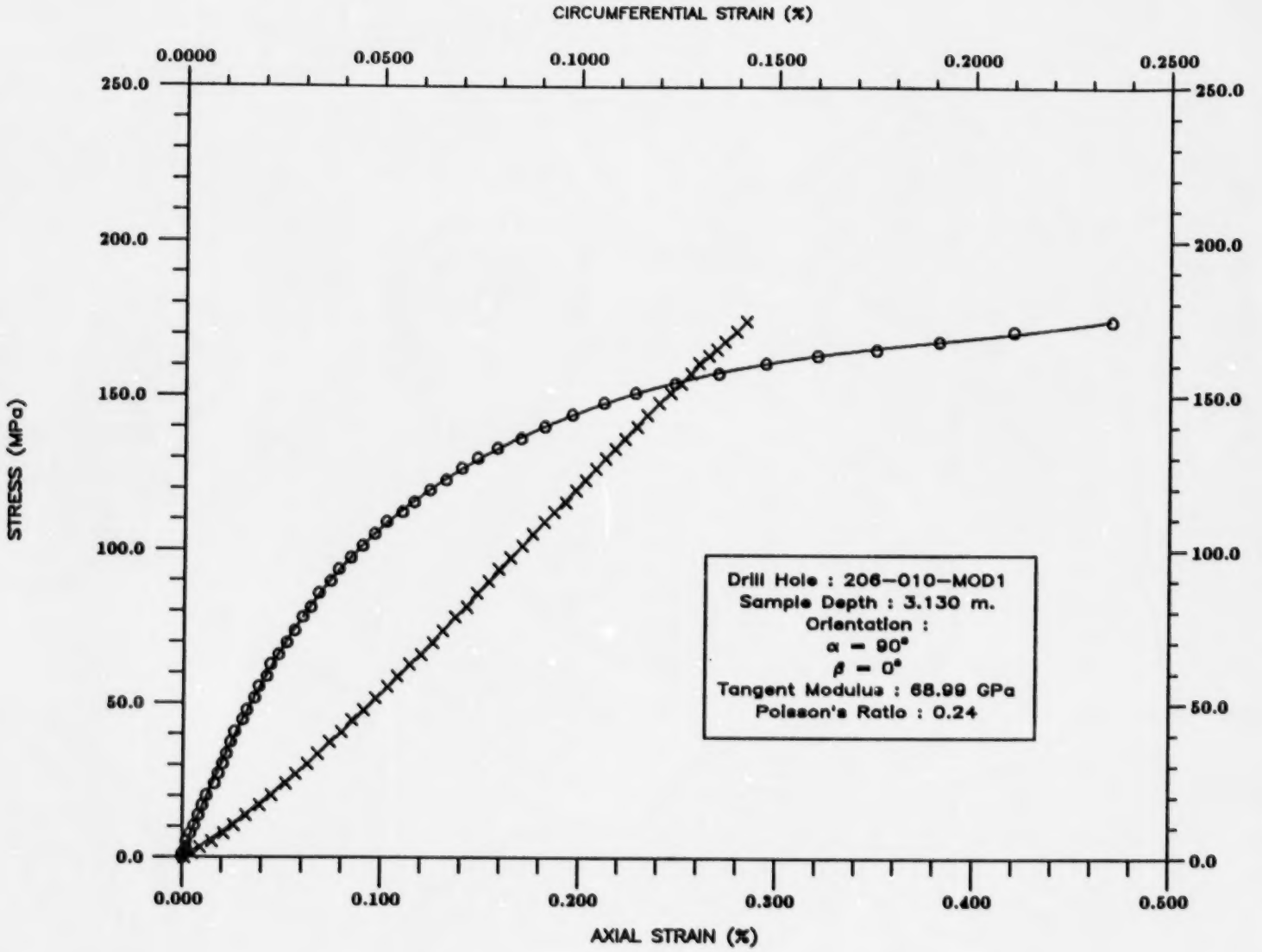

Fig. 1 : Axial and circumferential stress/strain curves for anisotropy test specimens.

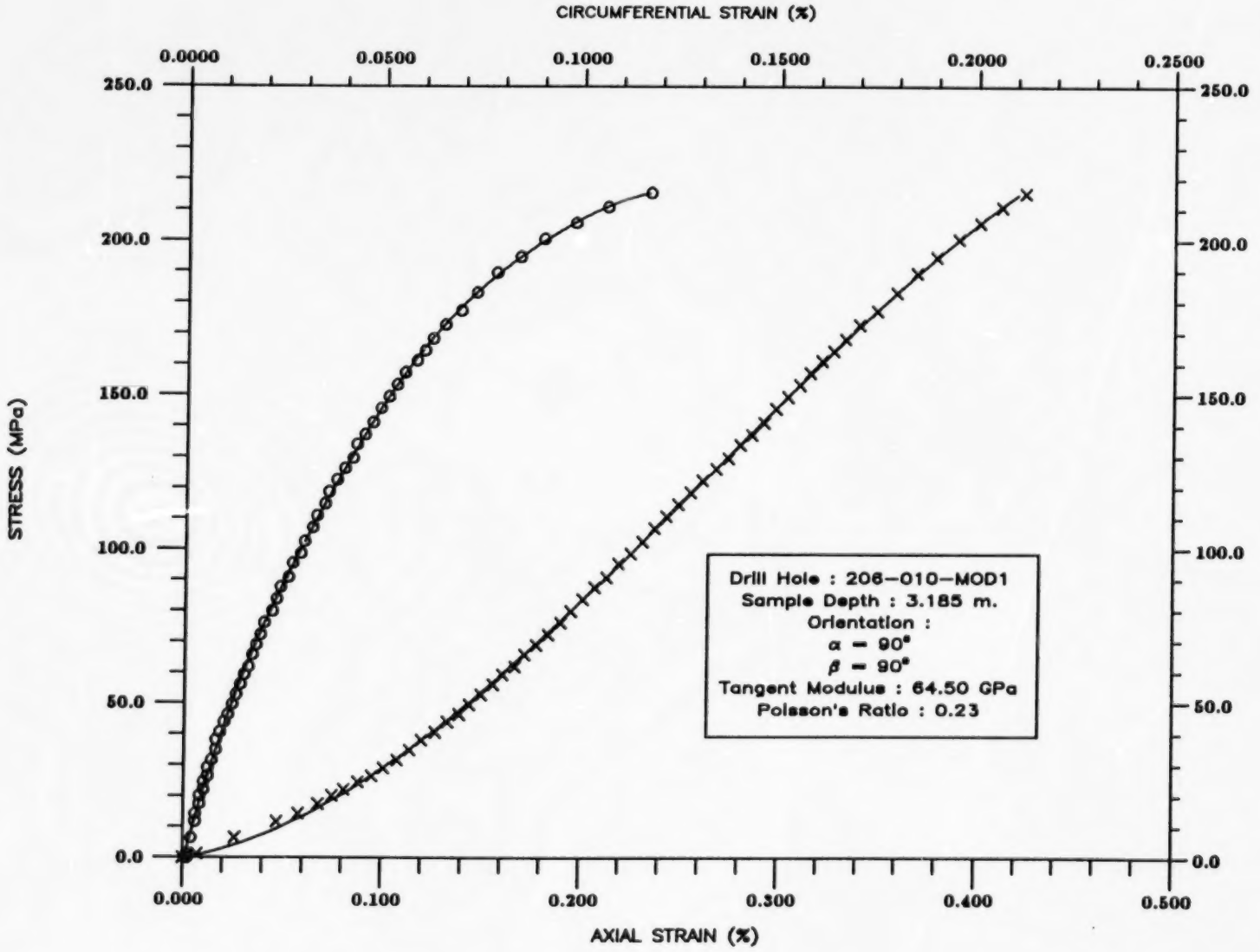

Fig. 2: Axial and circumferential stress/strain curves for anisotropy test specimens.

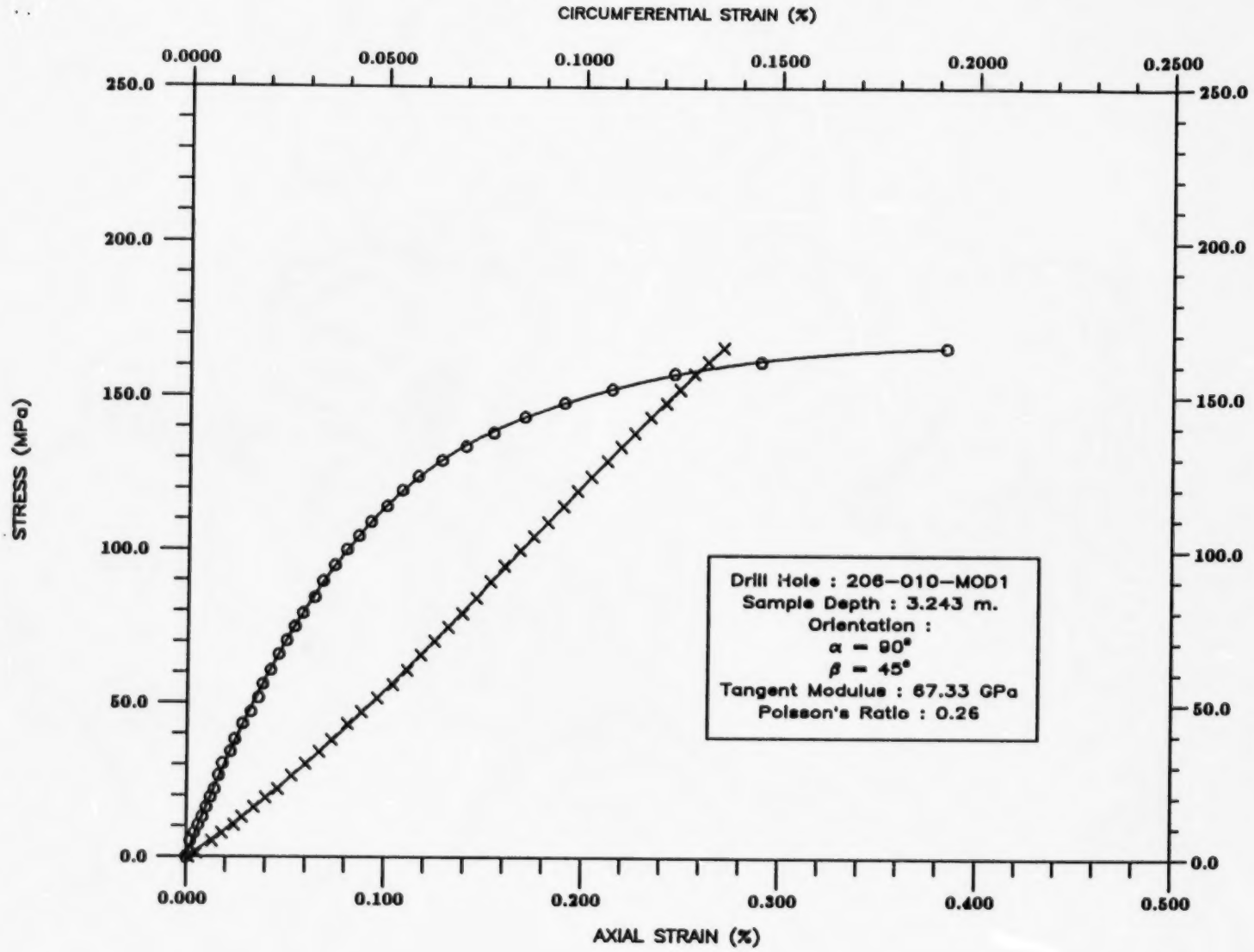

Fig. 3: Axial and circumferential stress/strain curves for anisotropy test specimens.

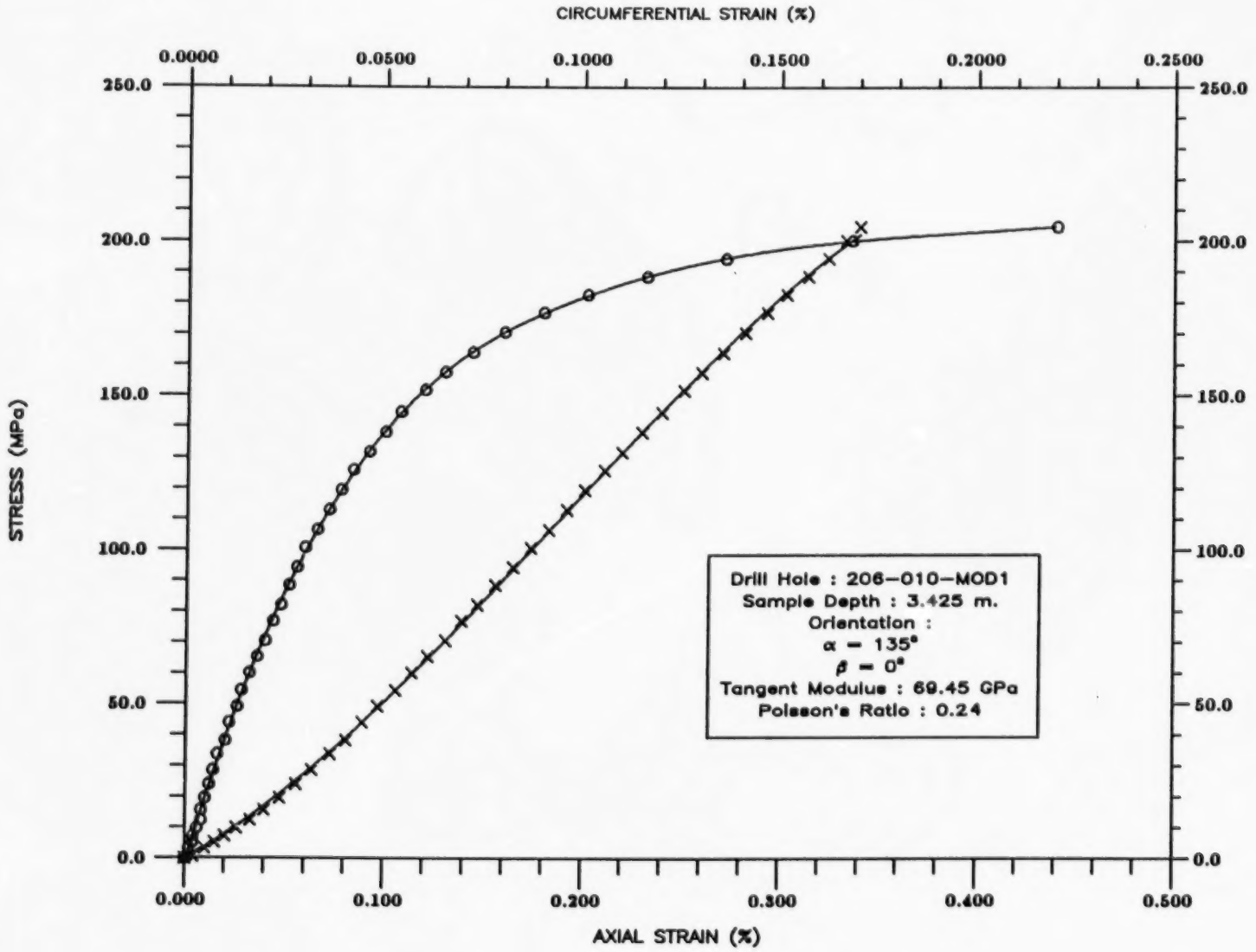

Fig. 4: Axial and circumferential stress/strain curves for anisotropy test specimens.

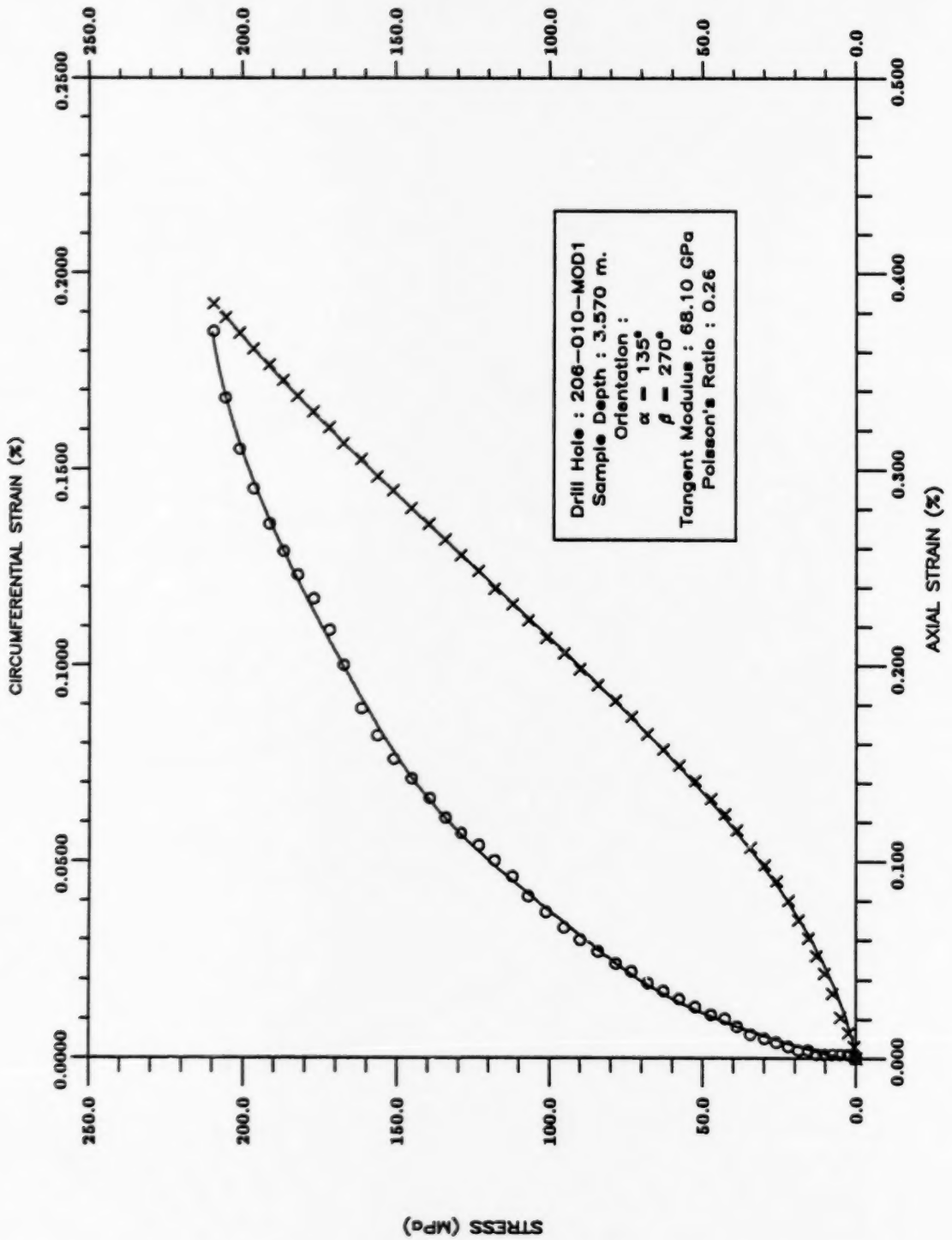

Fig. 5: Axial and circumferential stress/strain curves for anisotropy test specimens.

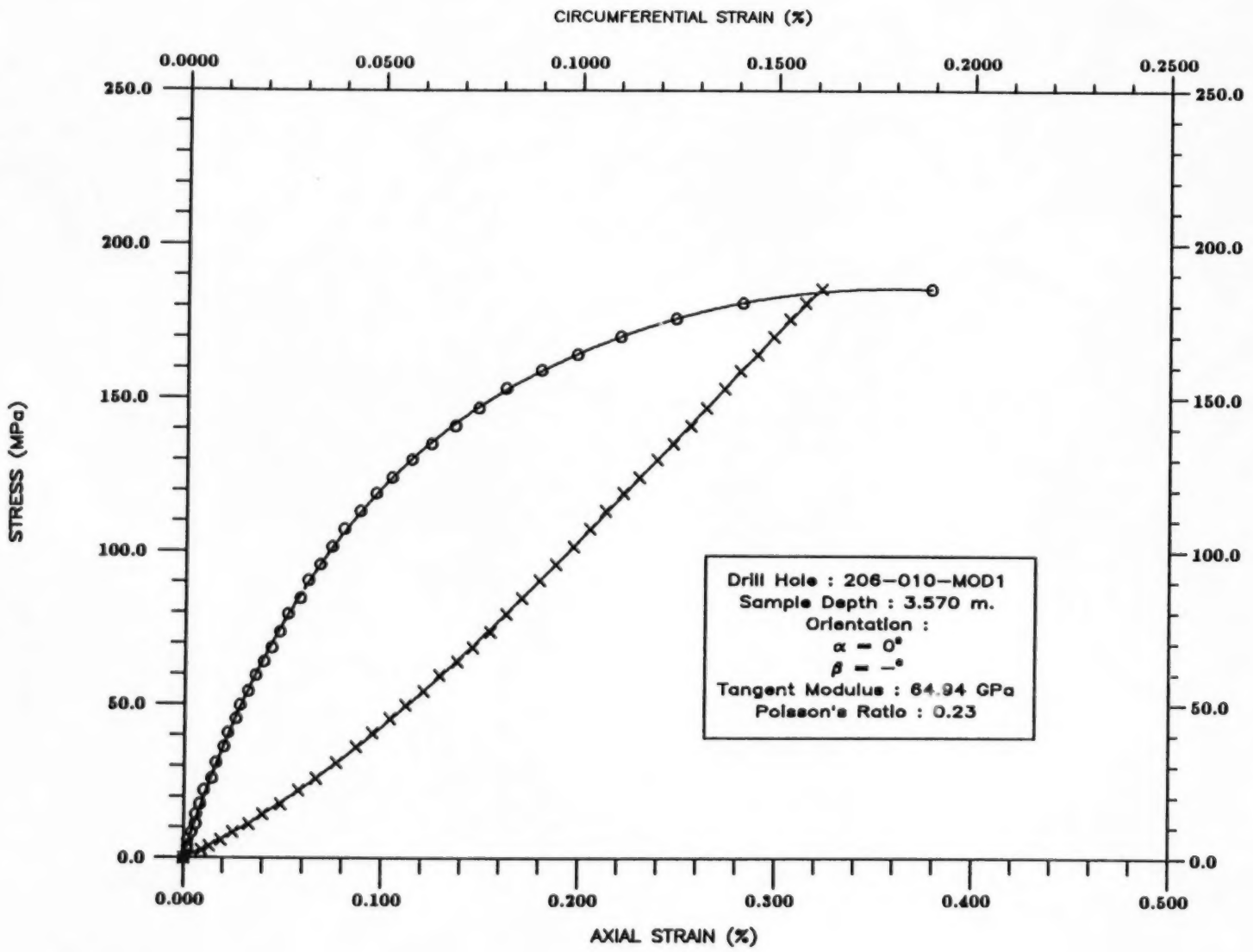

Fig. 6: Axial and circumferential stress/strain curves for anisotropy test specimens.

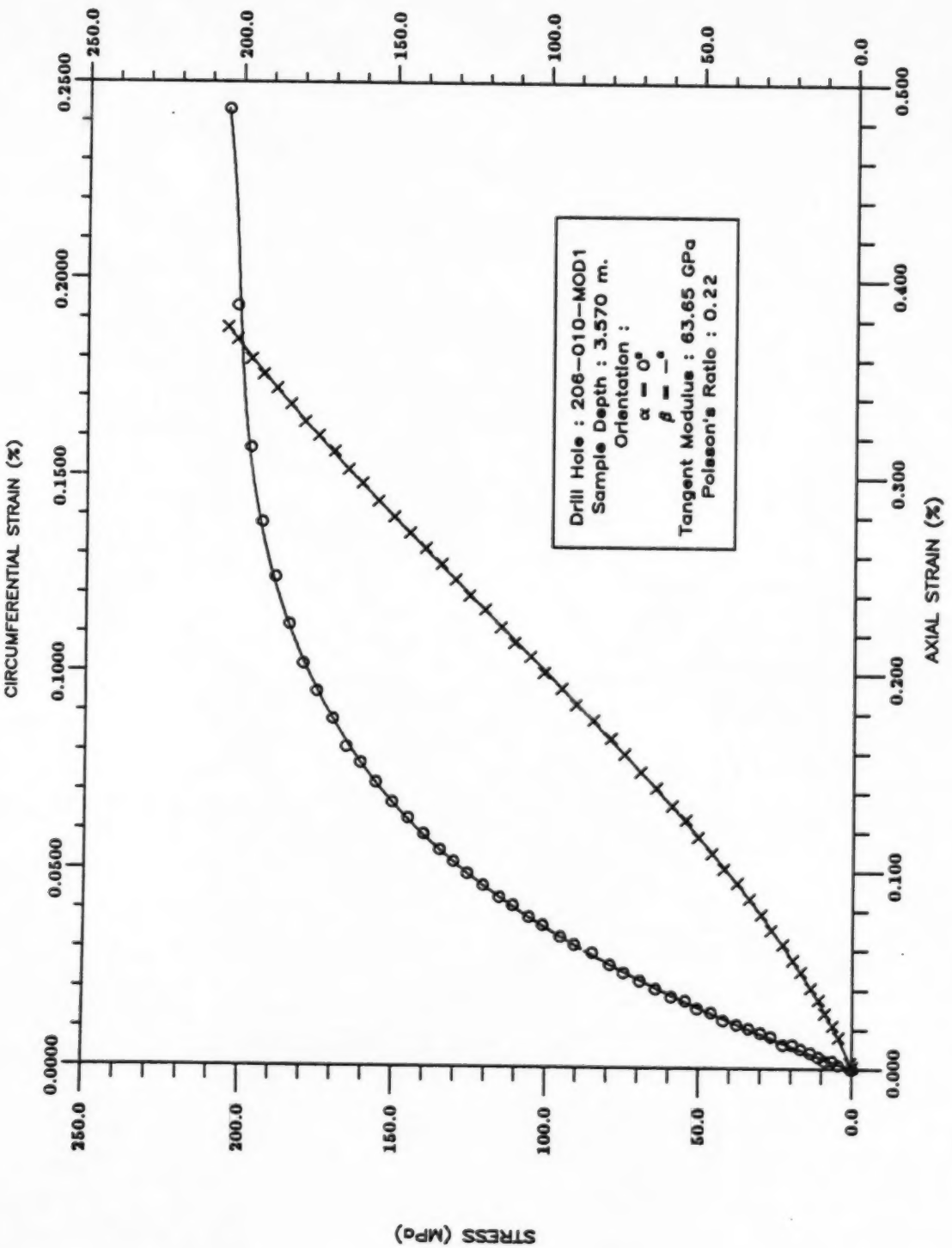

Fig. 7 : Axial and circumferential stress/strain curves for anisotropy test specimens.

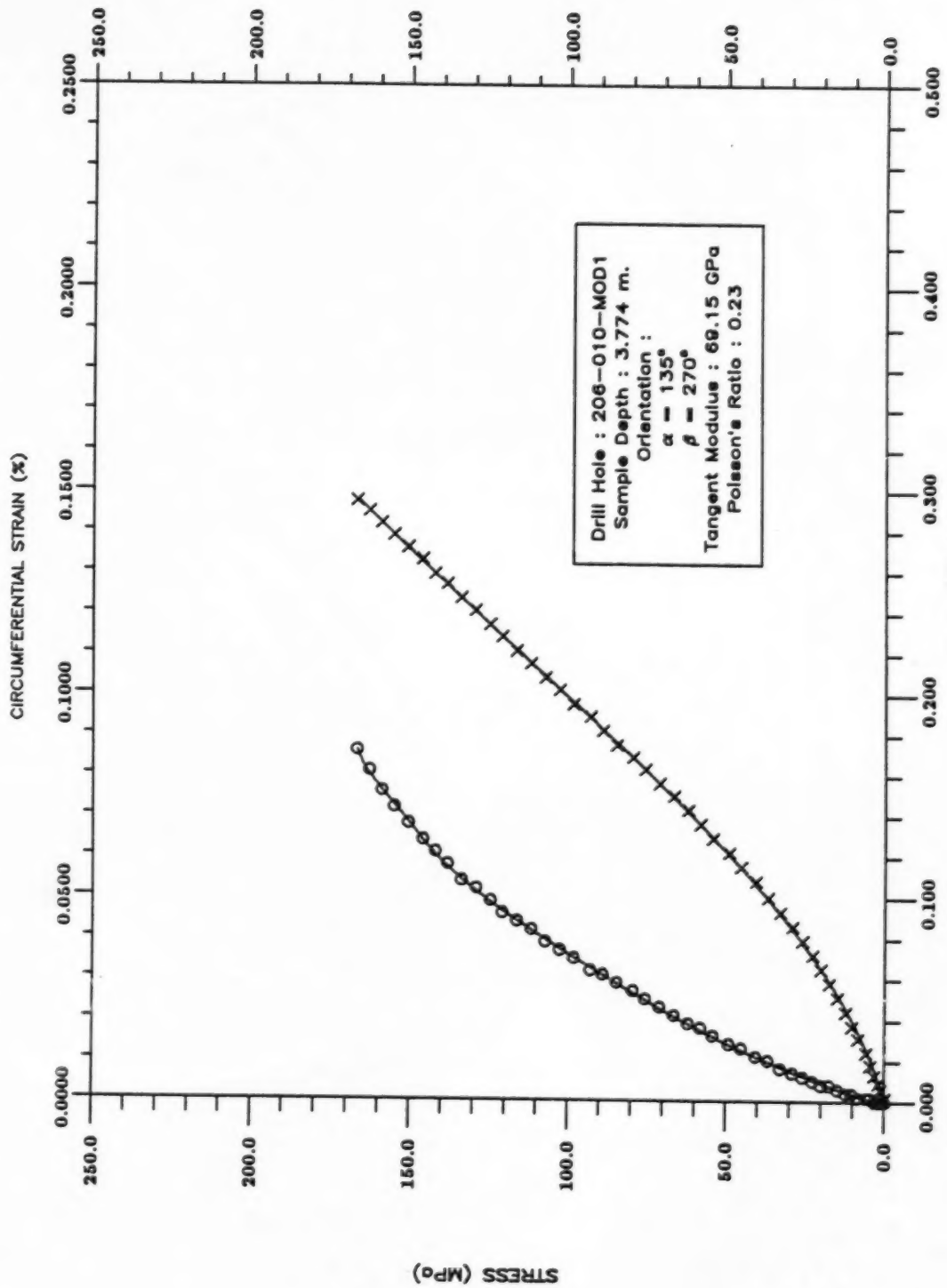

Fig. 8: Axial and circumferential stress/strain curves for anisotropy test specimens.

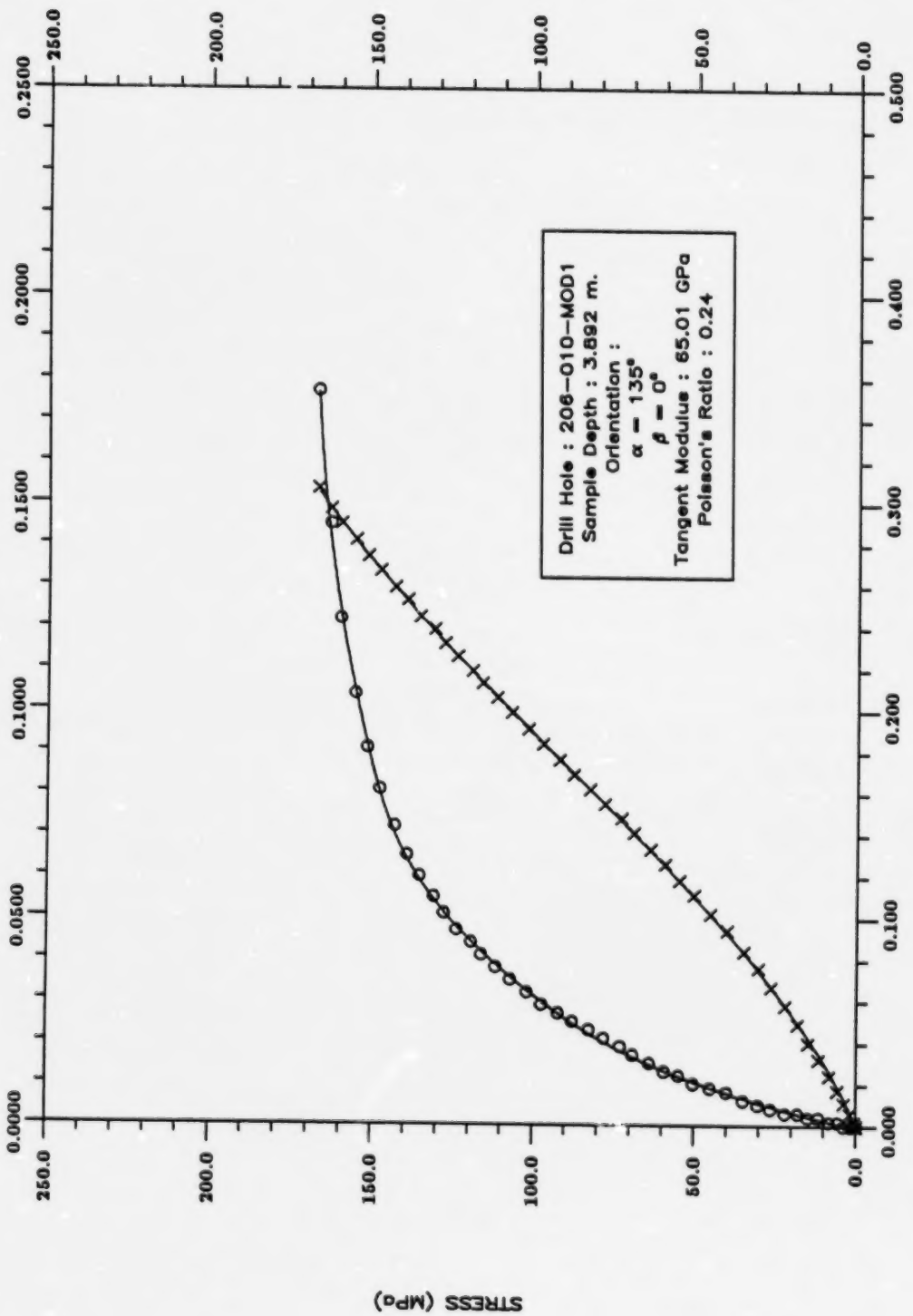

Fig. 9 : Axial and circumferential stress/strain curves for anisotropy test specimens.

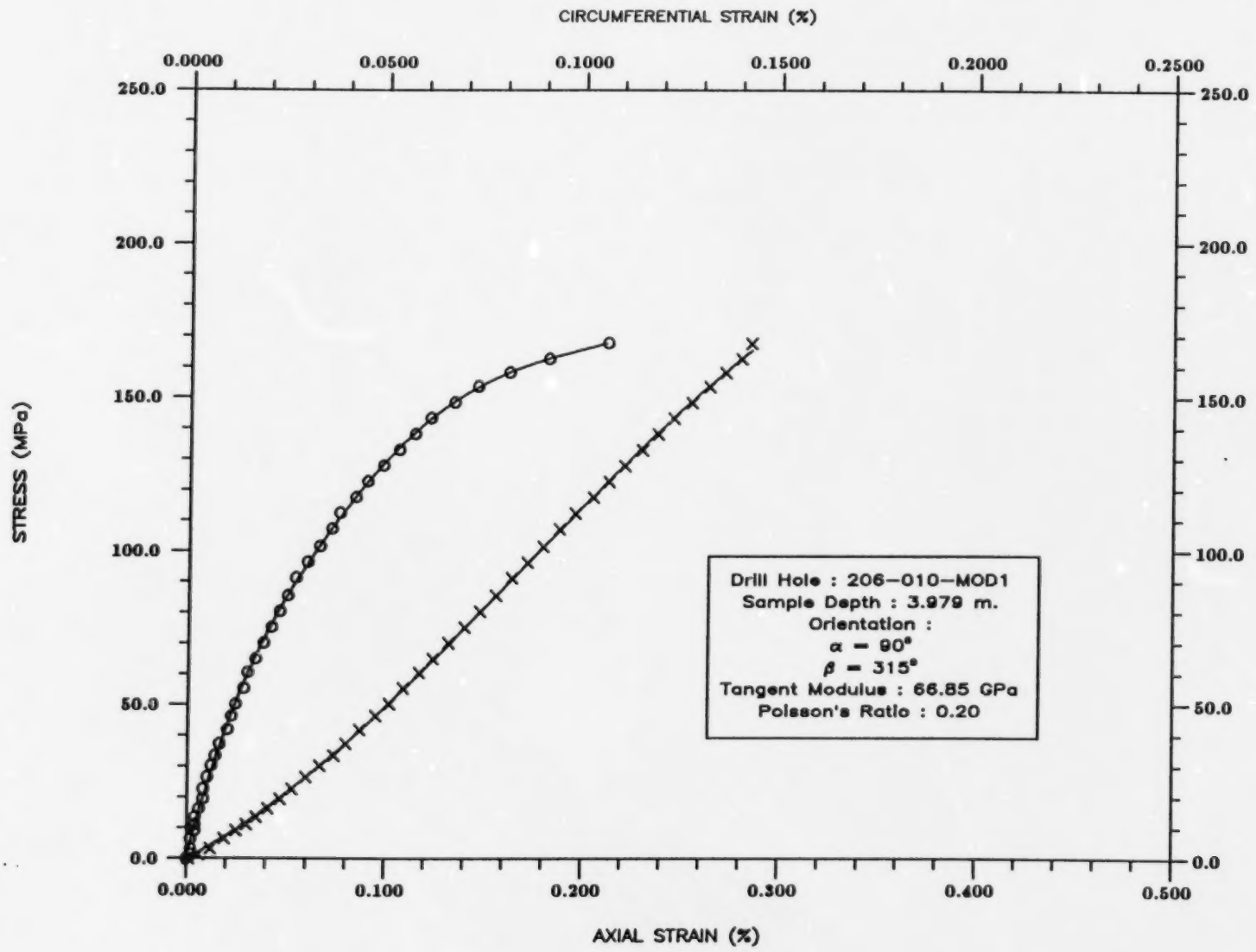

Fig. 10: Axial and circumferential stress/strain curves for anisotropy test specimens.

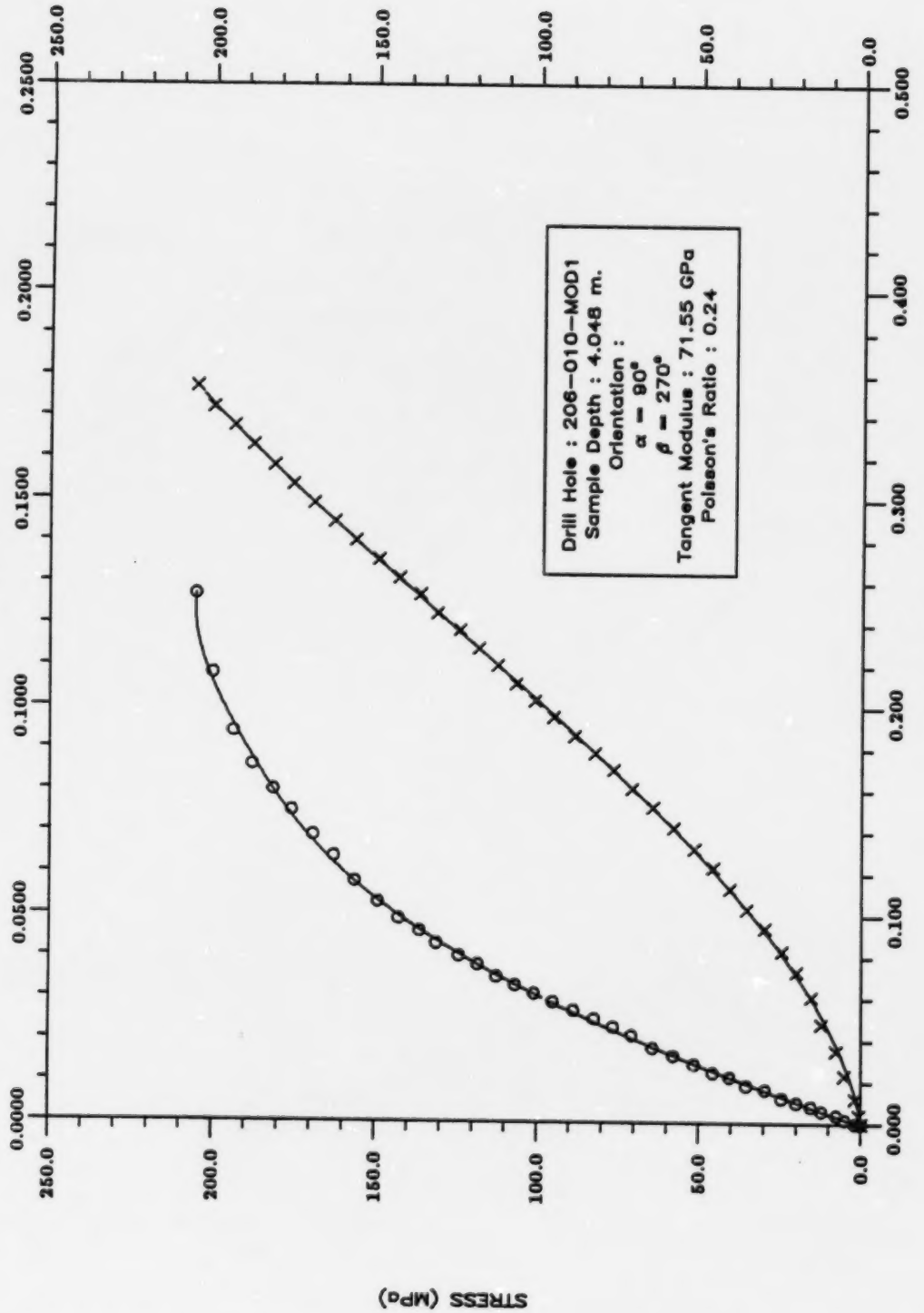

Fig. 11: Axial and circumferential stress/strain curves for anisotropy test specimens.

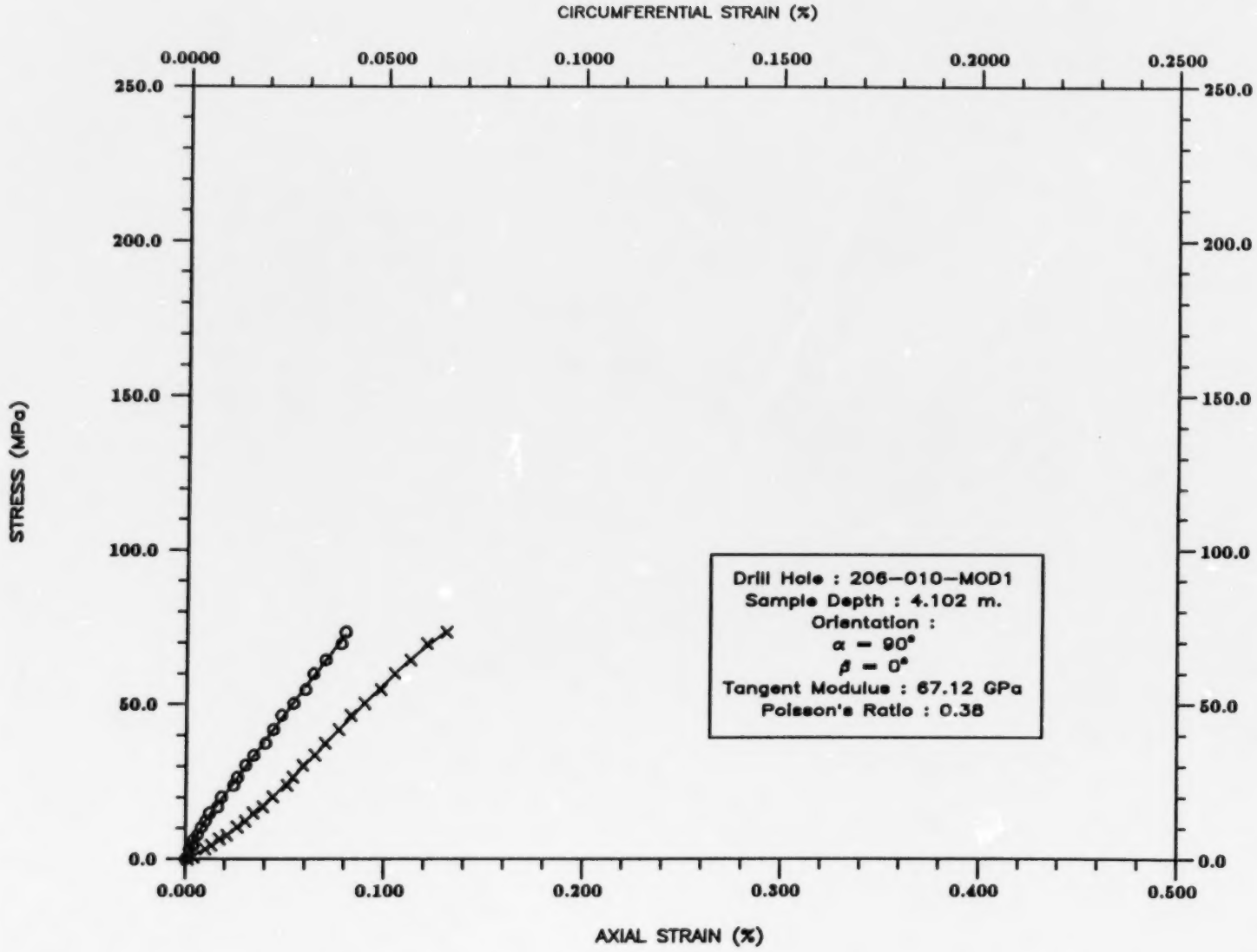

Fig. 12: Axial and circumferential stress/strain curves for anisotropy test specimens.

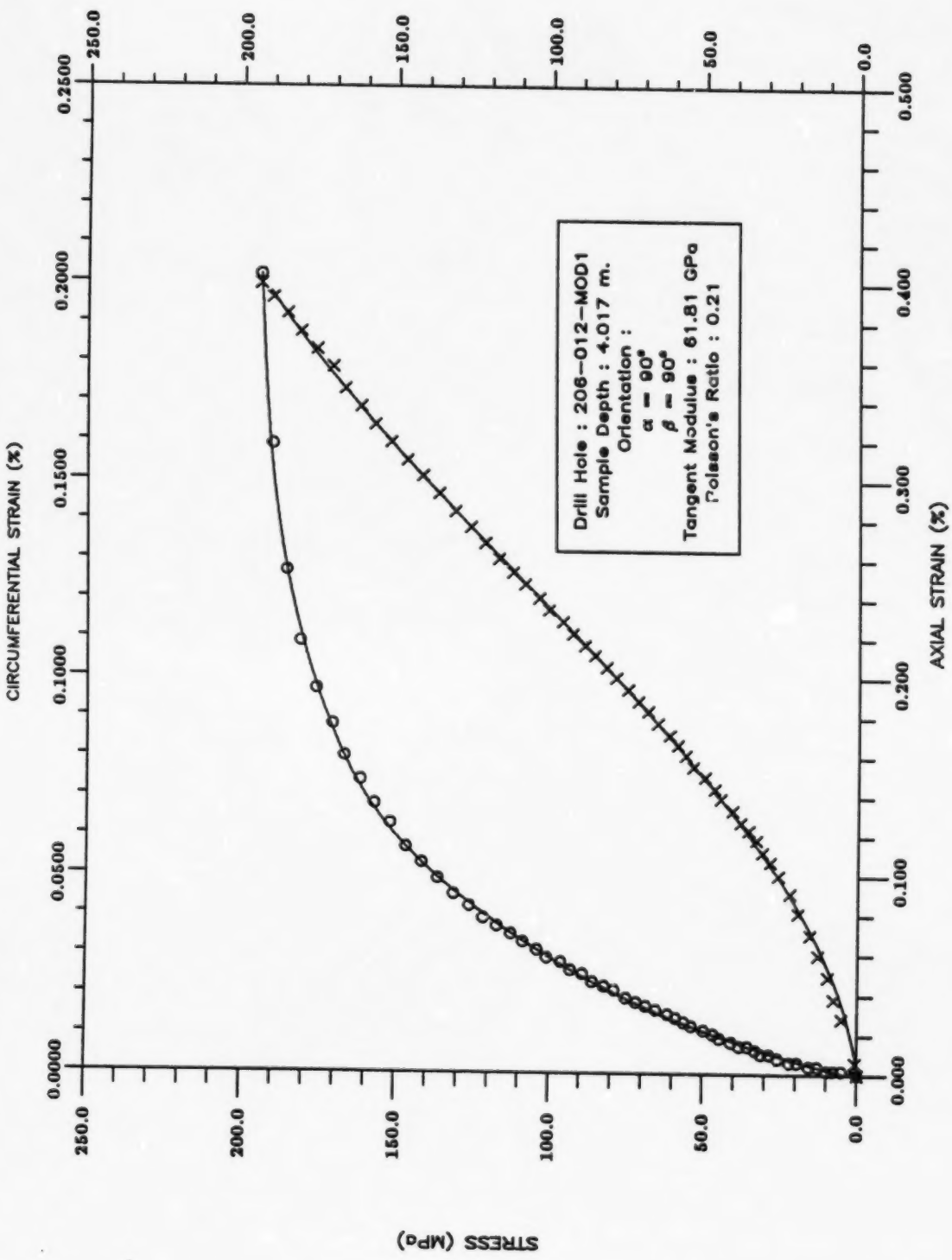

Fig. 13: Axial and circumferential stress/strain curves for anisotropy test specimens.

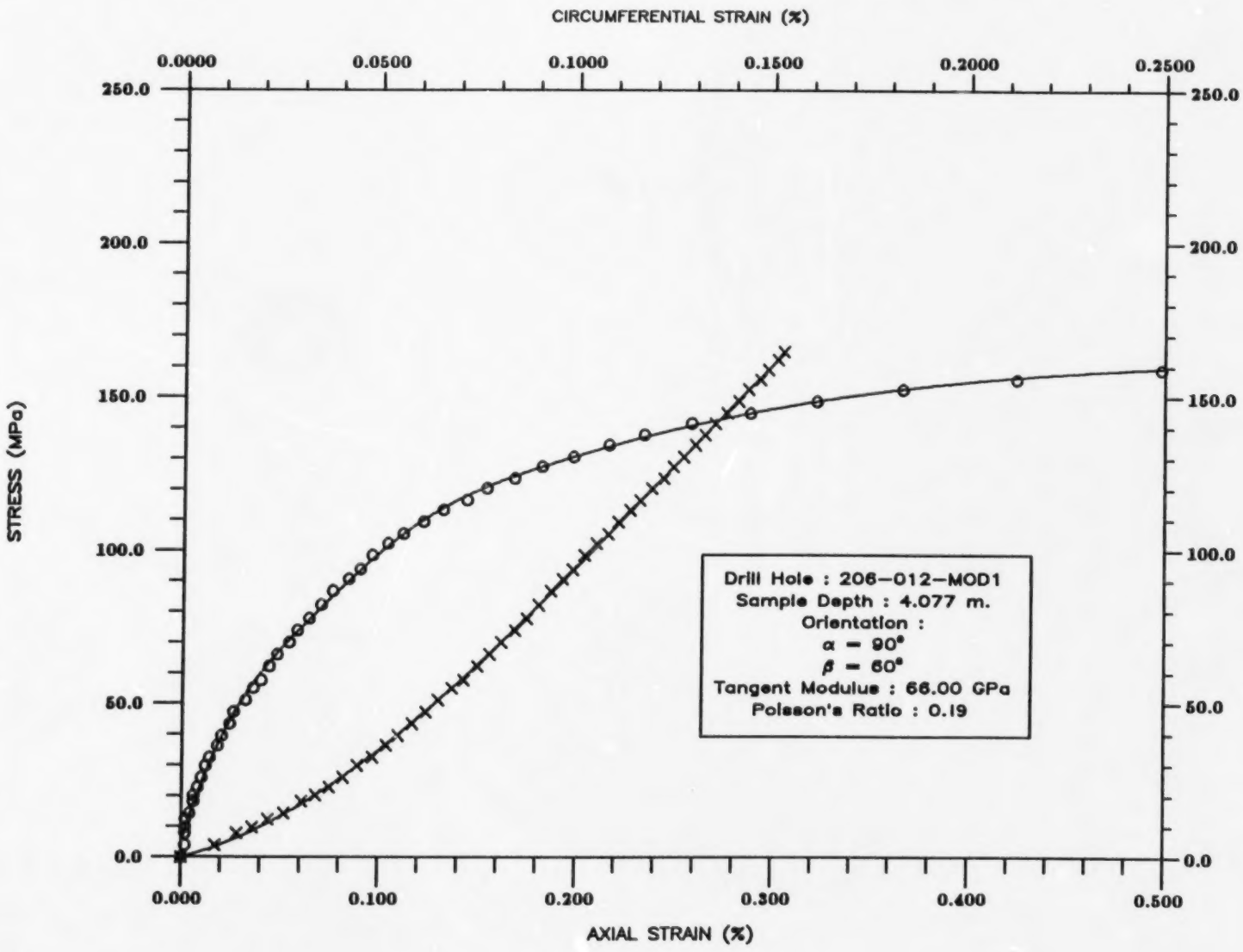

Fig. 14: Axial and circumferential stress/strain curves for anisotropy test specimens.

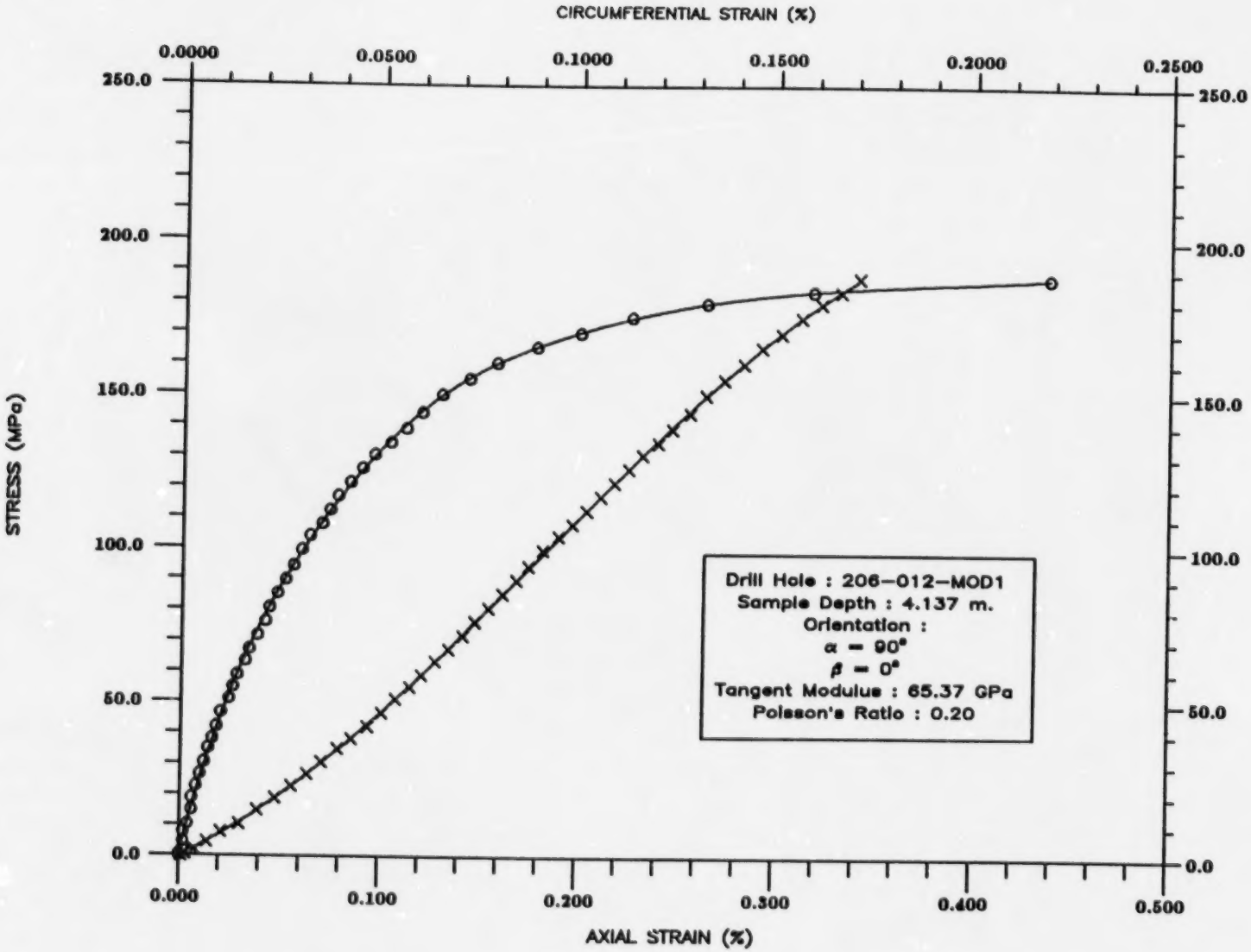

Fig. 15: Axial and circumferential stress/strain curves for anisotropy test specimens.

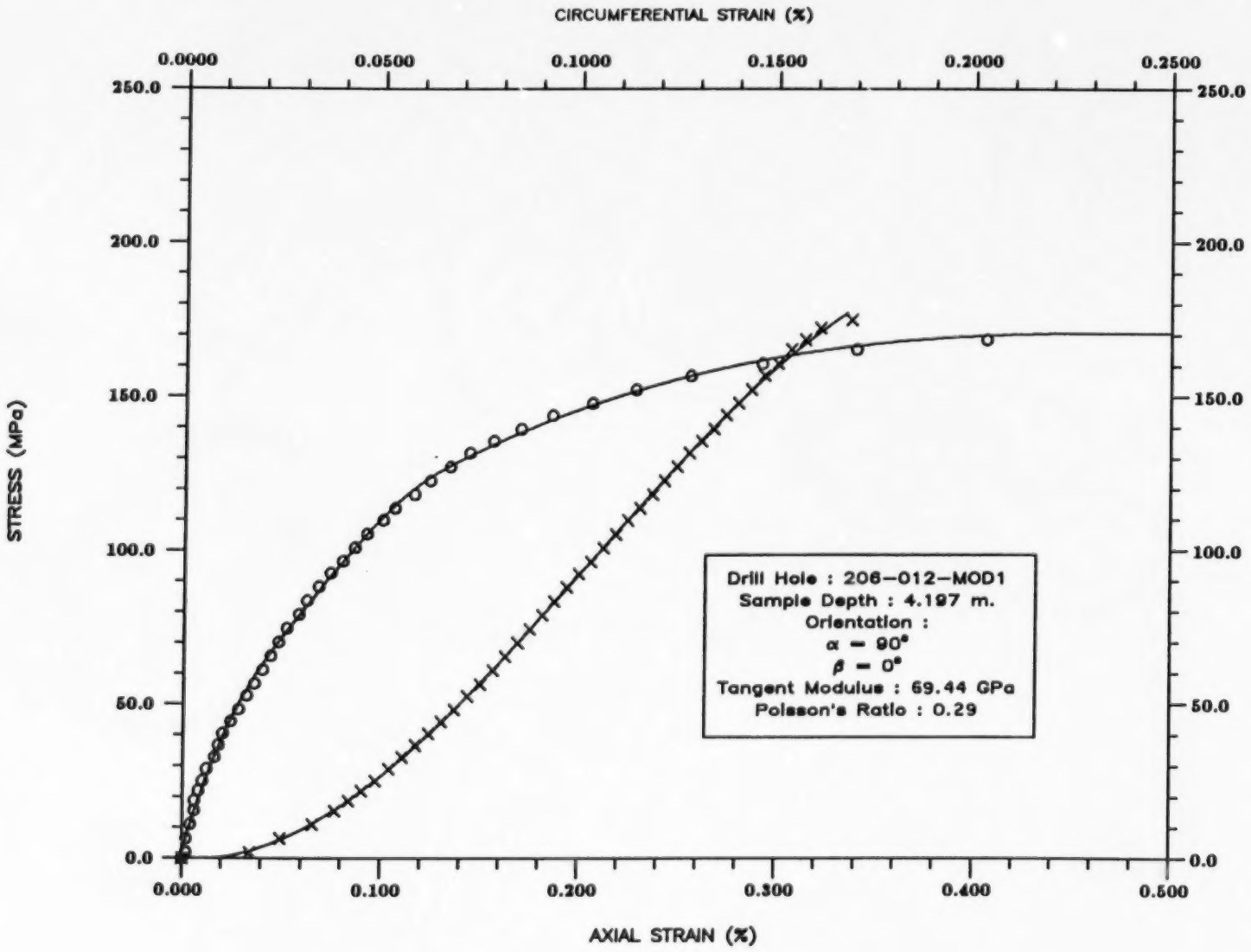

Fig. 16: Axial and circumferential stress/strain curves for anisotropy test specimens.

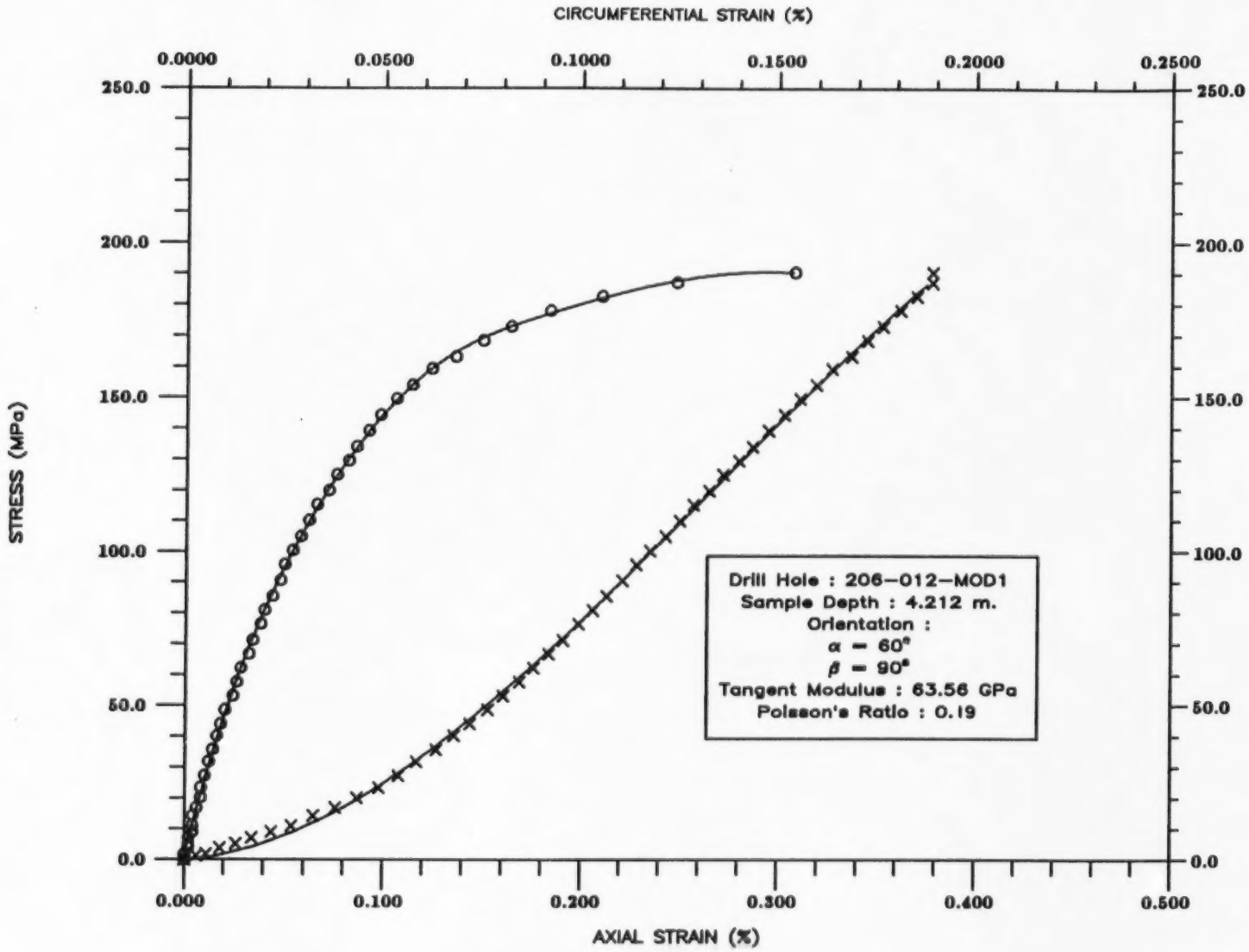

Fig. 17: Axial and circumferential stress/strain curves for anisotropy test specimens.

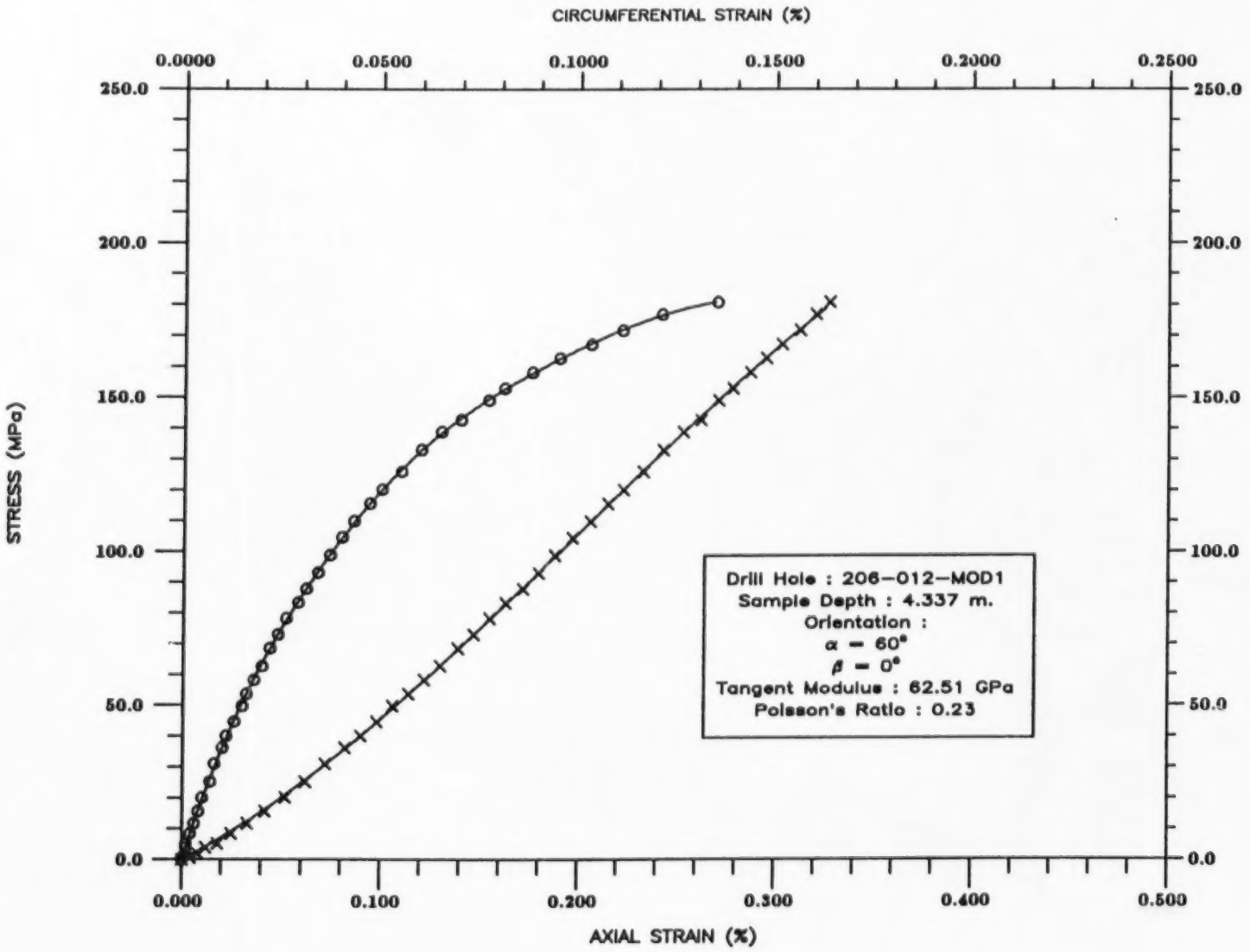

Fig. 18: Axial and circumferential stress/strain curves for anisotropy test specimens.

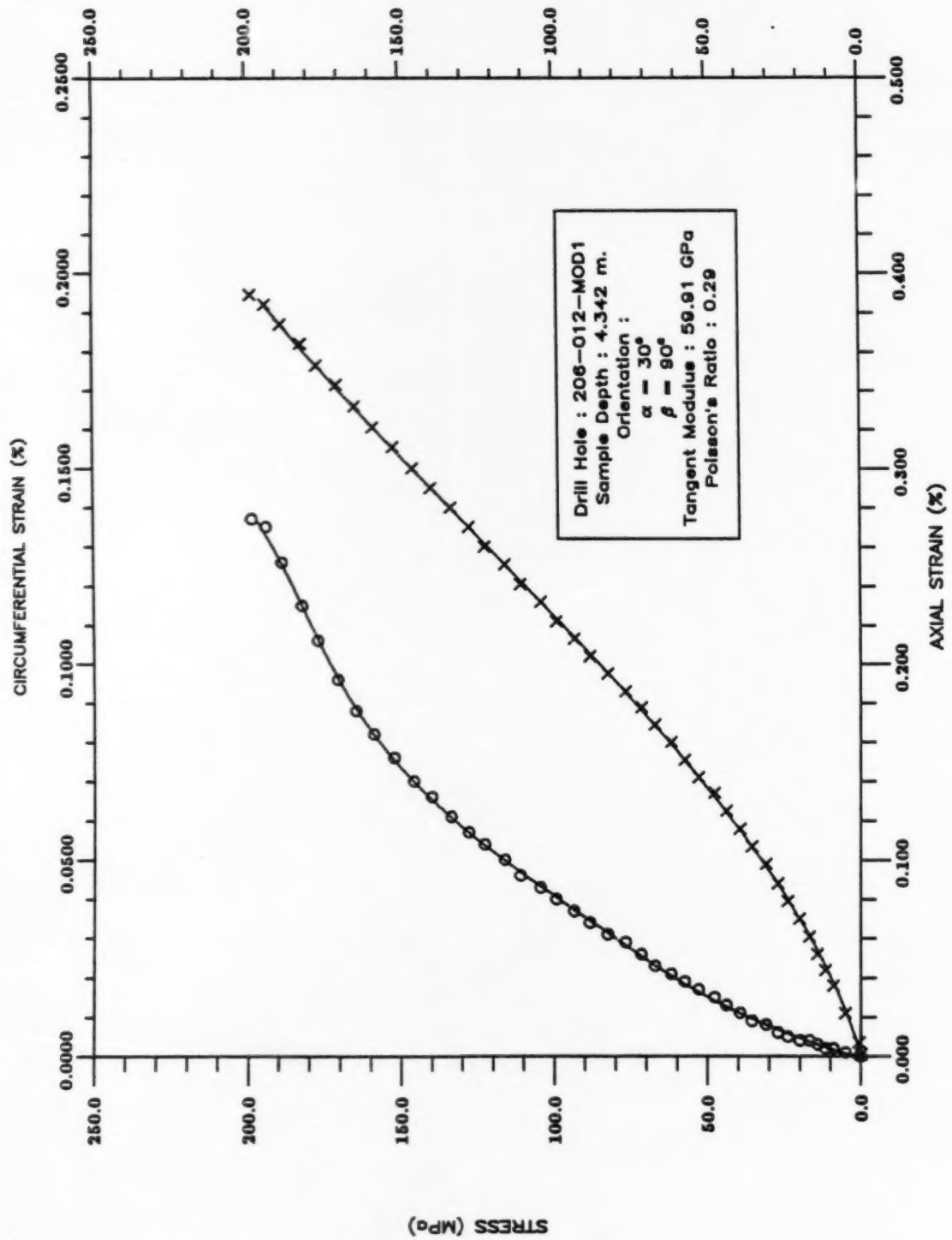

Fig. 19: Axial and circumferential stress/strain curves for anisotropy test specimens.

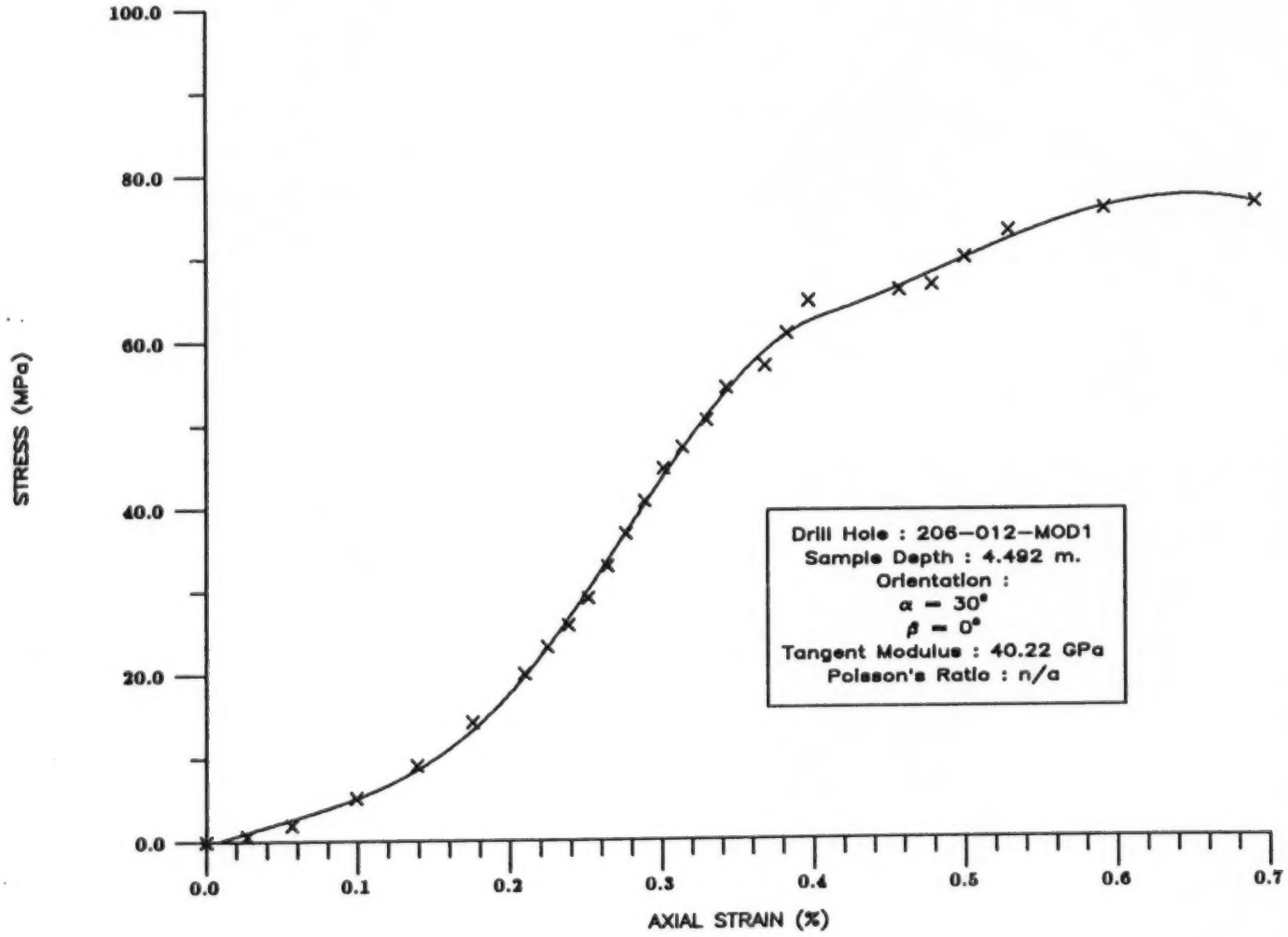

Fig. 20: Axial and circumferential stress/strain curves for anisotropy test specimens.

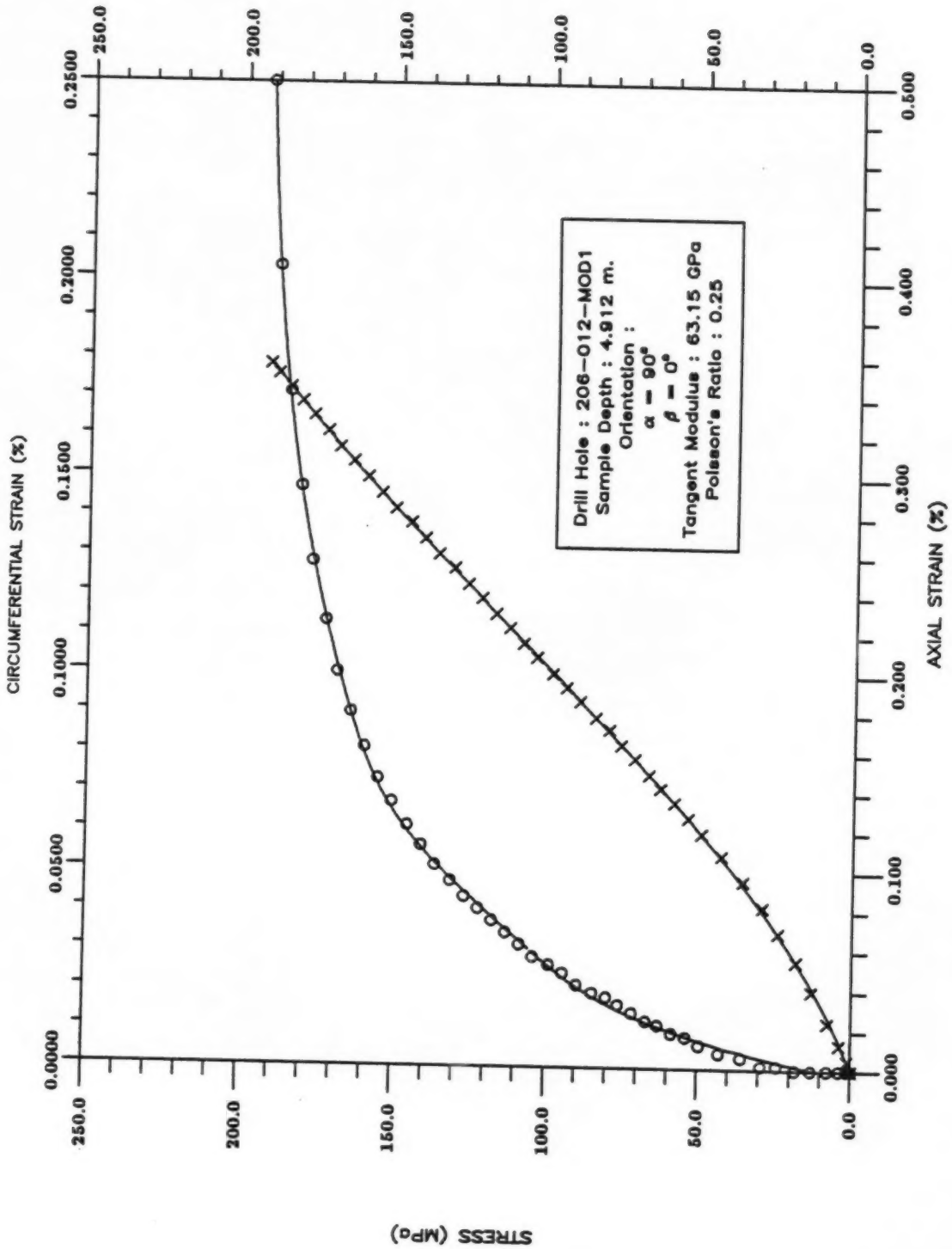

Fig. 21: Axial and circumferential stress/strain curves for anisotropy test specimens.